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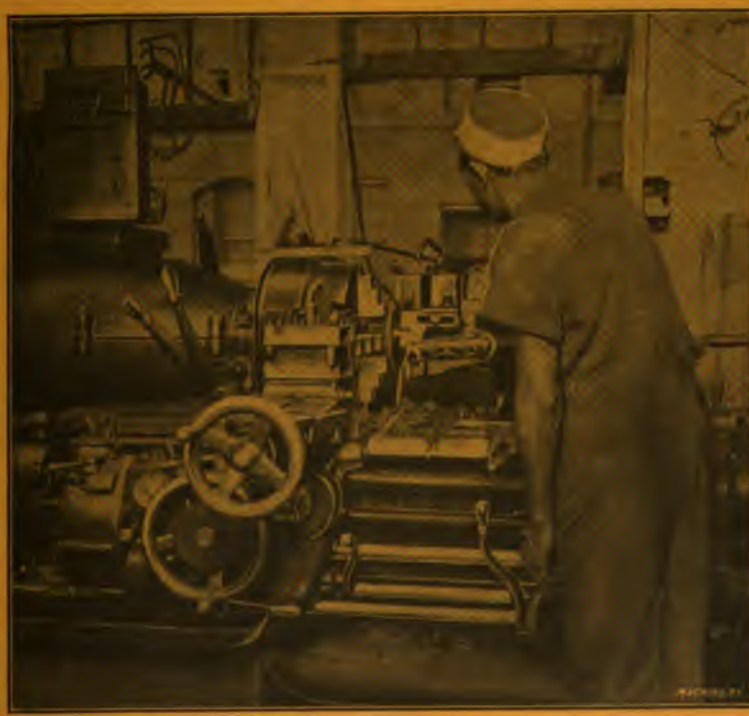
MACHINING TAPERED AND SPHERICAL SURFACES

BY ALBERT A. DOWD



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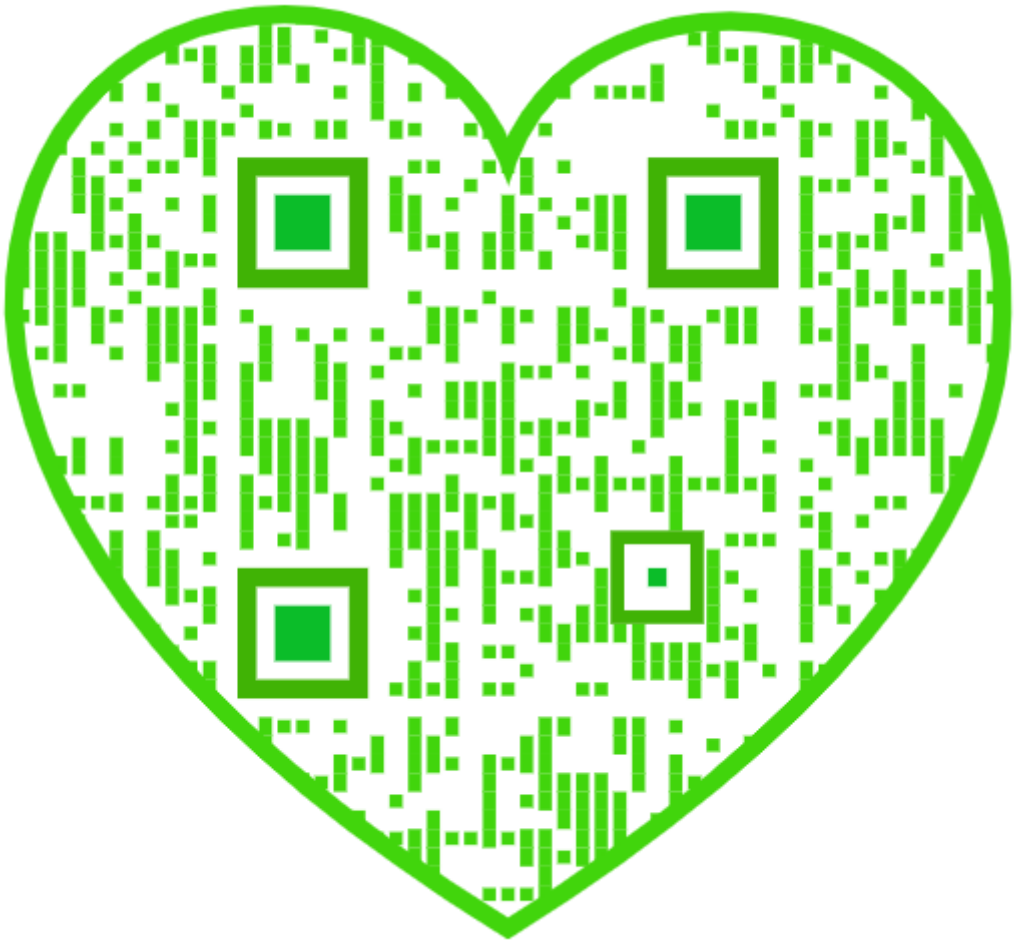

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By ALBERT A. DOWD

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CHAPTER I

TAPER BORING AND TURNING ATTACHMENTS

The proposition of accurately machining male and female tapered surfaces is one of almost daily occurrence in every factory, while the tapers required are of every degree of inclination. The materials on which the work is to be done are also varied, ranging from steel or brass bar stock of small diameter to cast iron or steel castings of great size. Conditions governing the work are widely different, as the number of pieces needed obviously makes a difference in the method of handling. When only one or two are required, and the size of the work is not prohibitive, the engine lathe is most frequently used, several well-known methods of generating the taper being possible on this machine, *viz.*, setting over the tailstock to the correct angle, when the work is of such a nature that it may be held on centers; using the compound rest with hand feed; and using the taper attachment with which nearly all modern lathes are equipped and which is too well known to need description. There are also occasional instances where the lathe may be used for manufacturing work of this kind in large quantities, by means of special attachments, although this is usually applicable to conditions requiring no other machining operations except the taper. As a general thing when the number of pieces is sufficiently large to warrant it, the work is performed on the horizontal screw machine or turret lathe, the vertical turret lathe or the vertical boring mill. Many ingenious schemes for generating tapers on these machines have been devised, the construction of a number of which will be described and illustrated in the following.

Taper Turning Devices for Bar Stock

On turret lathes or screw machines equipped for bar work, there are various devices for turning a taper on the bar. These tools are in many instances patented, and may be purchased of the manufacturers. Obviously there are such a number of these that it is out of the question to attempt to describe each one. Detailed information may be easily obtained on request.

Method of Finishing a Taper Hole without Generating the Taper

Before taking up the subject of generating devices for taper work, let us first consider a method much used in turret lathe practice and one which may be depended upon to give very satisfactory results, when absolute accuracy is not essential. When the tools are properly taken care of, good commercial work may be turned out by means of the tooling shown in Fig. 1. It will be noted that all the tools used are piloted in a bushing located in the chuck. The first tool used, shown at *A*, is a plain boring bar which serves to rough-bore the hole,

thereby producing an approximately true generated straight hole. The second tool *B* is a finish-boring bar which brings the hole to about the required size for the small end of the taper. The next tool *C*, is a roughing taper step reamer which removes the larger part of the stock left in the hole, and leaves the work in the form of a series of

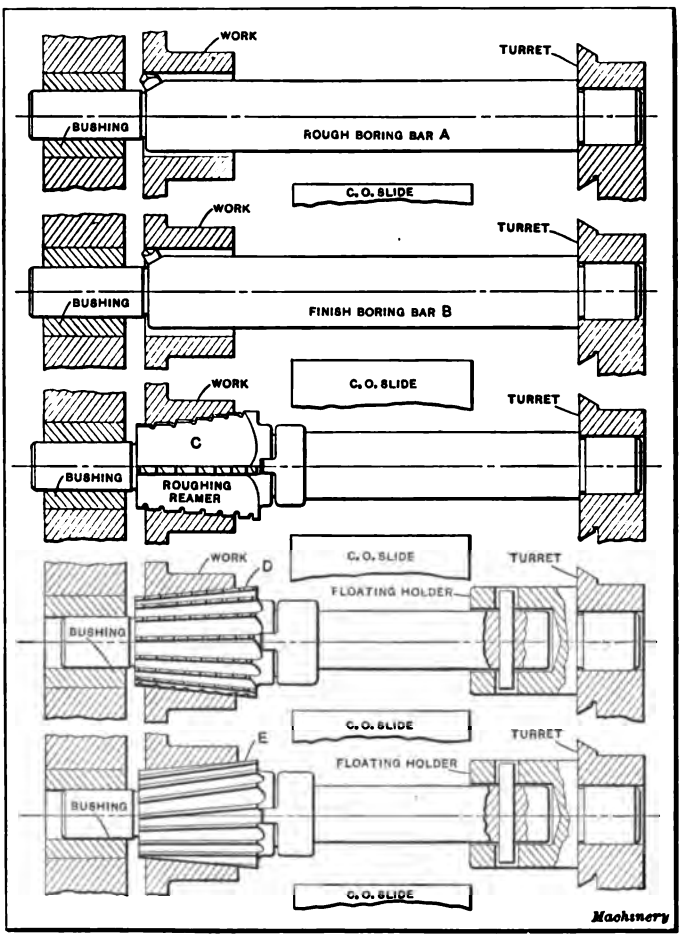

Fig. 1. Typical Boring Tools and Reamers for Taper Holes

grooves or steps with the angle of the correct inclination. A roughing taper reamer *D* is next used in a holder so made that the rear end of the reamer will float. It will be noted that this reamer is straight fluted but that a left-hand spiral groove with about ¾ inch lead is cut the entire length of the tool. This serves to break the chip and makes possible a much easier cutting action; there is also a tendency to prevent "pulling in." The hole is sized with another reamer of

the floating type *E* which may be either straight-fluted or made with a left-hand spiral of five to seven degrees, depending on the angle of the taper. The method shown here will not give as accurate results as may be obtained by generating the taper, but the sizing of the hole may be kept very nearly correct with little trouble, although slight variations in concentricity are bound to occur. One of the greatest objections to this manner of handling taper work is that the operator

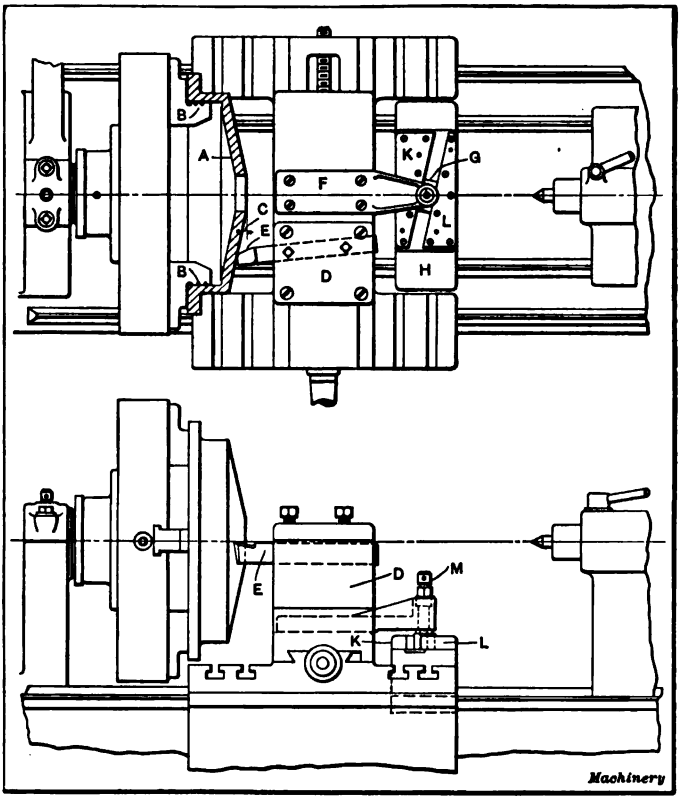

Fig. 2. Engine Lathe Attachment for turning Bevels

does not keep his tools up properly, and by being careless in regard to this matter, he leaves the reamers to do the most of the work and the results are therefore disastrous on account of the unequal wear on the reamer.

Taper Attachment for Producing a Conical Surface on the Engine Lathe

Fig. 2 shows an attachment fitted to the engine lathe for the purpose of producing the proper angle *C* on the head casting *A*. In this case the work is held in special jaws *B* which grip the interior of the casting as shown in the upper part of the illustration. The cross-slide is

equipped with a special tool-block *D* in which the tool *E* is held. The casting *H* was planed on its under side to fit the inner ways of the lathe and was clamped in position by means of straps not shown. Two steel plates *K* and *L* act as guides by which the proper taper is formed. These plates are hardened and the edges of the slot were ground parallel after assembling, to insure accuracy. A bracket *F*, fastened to the cross-slide, carries a pivoted steel block *G* which travels

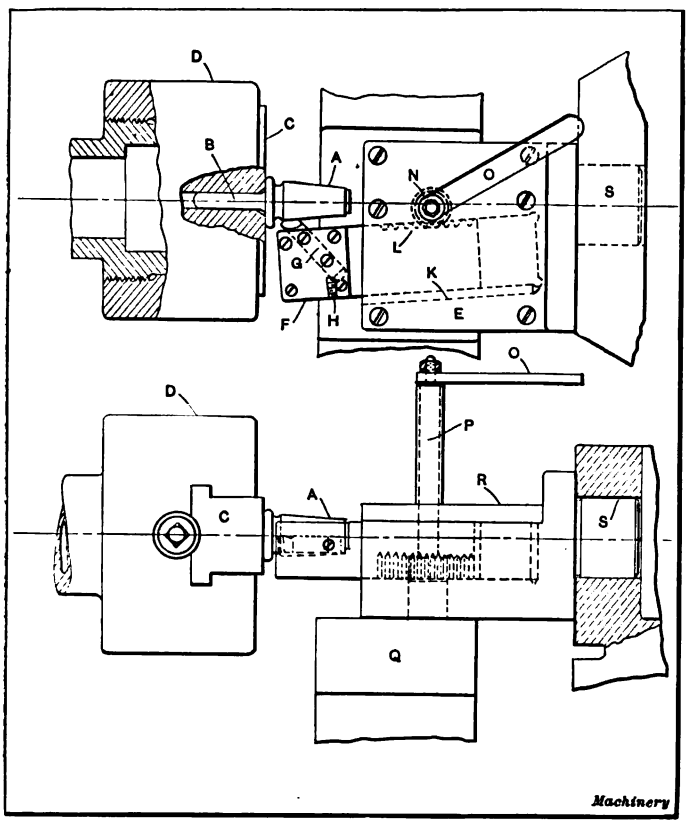

Fig. 3. Taper Attachment for Small Hand Screw Machines

in the slot, thereby controlling the movement of the carriage, and producing the desired taper. An oiler *M* acts as a gentle reminder that surfaces subject to friction are in occasional need of lubrication. The inner surface of casting *A* was machined on the same lathe in another setting, another set of forming plates being applied to the casting *H* to produce the required taper. This method of handling gave very satisfactory results.

A small brass cock, shown at *A* in Fig. 3 is a good example of an outside generated taper. The stem of the cock *B* is held in the special

jaws *C* of a two-jawed chuck *D*, this being obviously screwed to the spindle of a small hand screw machine. The taper turning attachment is entirely self-contained, and indexes with the turret. The entire attachment is made of steel with a shank *S* which fits the turret hole. The body *E* is carefully fitted on its under side to obtain a bearing on the steel block *Q* which is fastened to the cross-slide. This support is of considerable help in taking up vibration and thereby preventing

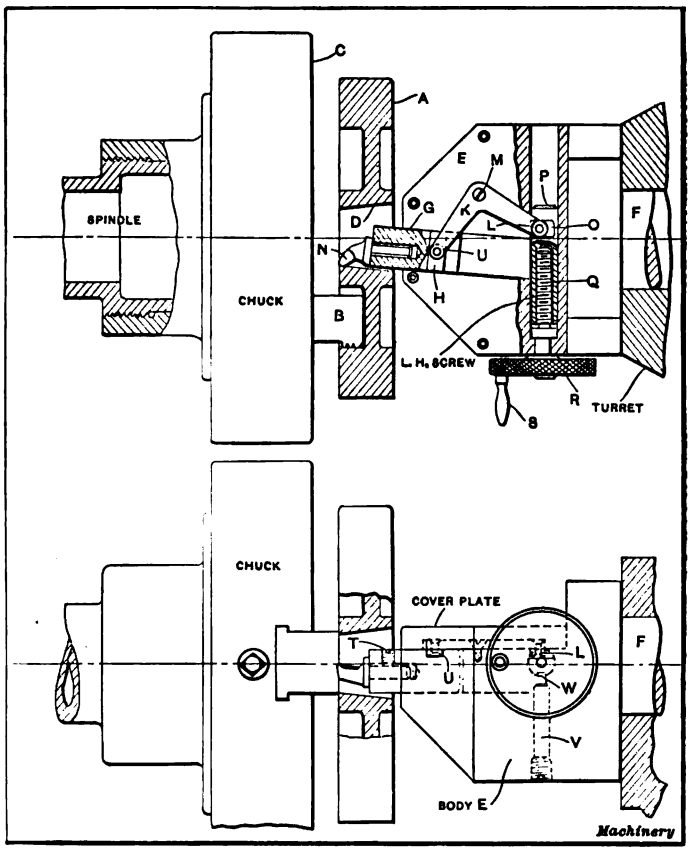

Fig. 4. Attachment for generating Small Taper Hole in a Motor-cycle Flywheel

chatter. The slide *F* fits a slot in the fixture which has been planed to the proper taper and the gib *K* acts as a take-up for wear. The cutting tool *G* is of rectangular section and accurately fits a slot in the front end of the taper slide. The headless set-screw *H* assists in setting the cut to obtain the proper diameter. A rack *L* is cut along one side of the slide and meshes with the pinion *N*, the shank *P* of which runs up through the body of the fixture and is operated by the lever *O*. A cover plate *R* is carefully fitted and keeps the parts in

position. Tools of this type are much used on small brass work and the work accomplished by them is excellent where very little stock is to be removed. They are built to generate a certain specified taper and can be used for no other.

The rather complicated little attachment shown in Fig. 4 was built for a final finishing cut in the taper hole *D* of the motor-cycle flywheel

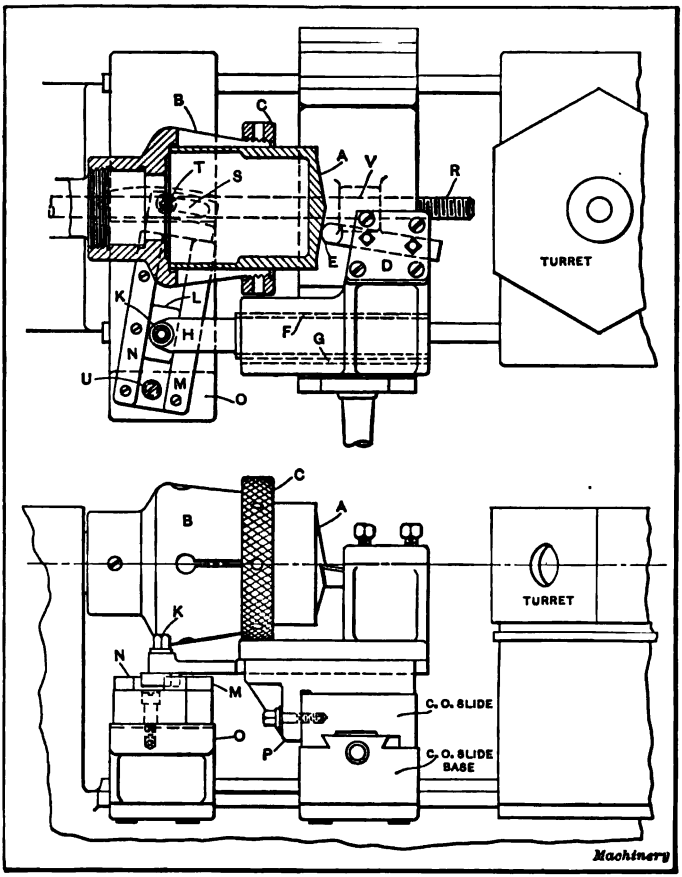

Fig. 5. Turret Lathe Taper Attachment for machining the End of an Automobile Engine Piston

A. In spite of the fact that the attachment itself is inclined toward multiplicity of moving parts, its action was so satisfactory that a duplicate order was received a few months after the original tool had been built. It will be noted that the jaws *B* of the three-jawed chuck *C* grip the work on the inside of the flange, and hold it far enough away from the chuck to permit back cutting on the hub and flange, thereby permitting the work to be finished in one setting. The body of the attachment *E* is made from a piece of round steel stock beveled

on the front end and with the shank *F* turned at its rear end to the proper diameter to fit the turret hole. The taper slide *G* fits an angular slot cut in the body of the attachment and is reamed at its front end to receive the shank of the cutting tool *N*. This tool is forged to the shape shown and is carefully ground to gage. As the amount of metal which this tool removes is very slight, it requires regrinding only at long intervals. A headless set-screw *T* secures it in position. The bell-crank *K* is pivoted at *M* and the hardened steel rollers *L* and *U* are located at the two ends. The roller at the forward end operates at the slide by its action in the slot *H*, while the roller at the other end enters another slot *O* in the operating pin *P*. A teat screw *V* enters the spline *W* cut in the under side of the operating pin, thereby preventing it from turning. The small knurled handwheel *R* contains a little finger handle *S* which is used to revolve the screw *Q*. The rod *P* is tapped out to receive this screw, and obviously is moved forward or backward by its action, the motion being carried forward through the bell-crank to the operating slide.

Turret Lathe Taper Attachment for the End of an Auto Piston

The automobile piston shown at *A* in Fig. 5 has been finished on the outside but the end has not been formed to the required taper. It is held in a special spring chuck *B* which is closed in on the end by the tapered screw collar *C*. In this instance there were several conical headed pistons to be taken care of, the angle of the cone varying slightly in each case. The turret lathe selected for use in this operation was of a standard make, and the longitudinal movement of the cut-off slide was controlled by the screw *R* engaged with the nut *V* on the under side of the slide. This screw was operated by a handwheel and was not coupled up with the feed mechanism. It was used principally to move the slide back and forth along the ways to any desired location. It will be seen that in this instance any sort of floating action in a longitudinal direction was out of the question and it was therefore necessary to design a special tool block *D* having a dovetail slide *F* and an extension *H*, at the end of which the hardened and ground steel block *L* was located, pivoting on the screw pin *K*. A swivel block containing two parallel plates *N* and *M* may be swung on the shouldered screw *U*, to suit the various angles. The curbed slot *S* permits the necessary movement, while the binder *T* secures it firmly. The swivel is mounted on the bracket *O*, which is gibbed to the ways in such a way that it may be moved to any desired location. When the attachment is used the cut-off slide cross-feed is thrown into gear and the angularity of the swivel block determines the movement of the tool *E*. As a point in design, attention is called to the way in which the tool block is carried over the edge of the slide at *P*, for the purpose of obtaining rigidity and preventing any chance of side slip. The writer knows of a number of instances where attachments of this kind have been used with very gratifying results.

The bevel gear shown at *B* in Fig. 6 is held in the three-jawed chuck at *C*, by means of soft jaws, and the tools *M* and *N* are used for rough-

ing and finishing the face of the gear, the spacing of the tools being such that the finishing tool takes up the work as soon as the roughing tool has completed its cut. This entire mechanism is special.

The carriage *S* is gibbed to the ways in the usual manner and upon this carriage is mounted the swivel slide arrangement *D*. This slide may be swung to any angle within its range and securely fastened. It

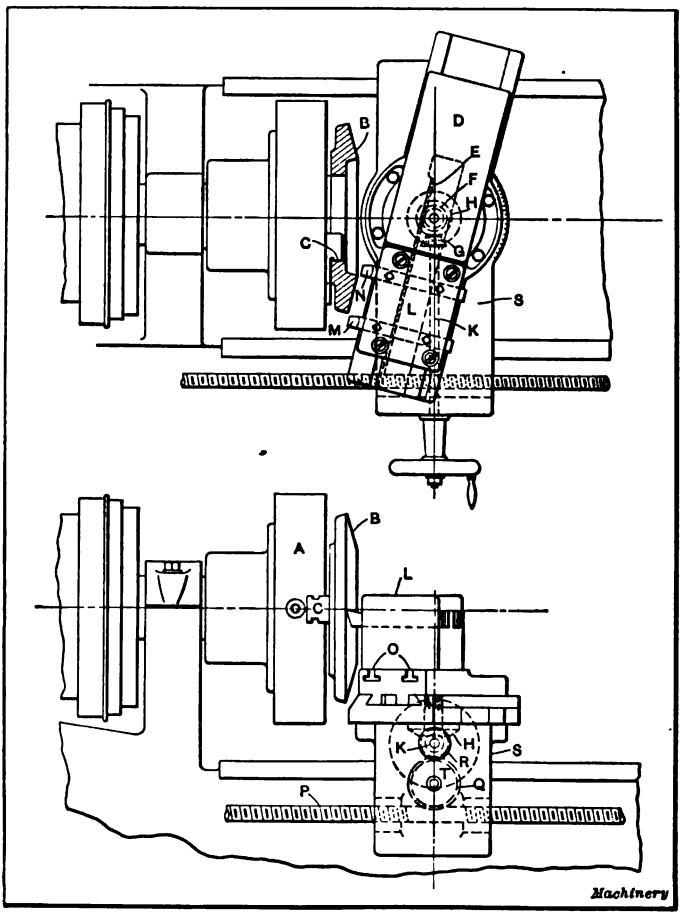

Fig. 6. Adjustable Cut-off Slide Attachment

will be noted that the feed-screw *P* meshes with the wormwheel *Q*, and the movement is transferred through the spur gears *T* and *R* to the shaft *K*. At the inner end of this shaft the pinion *G* meshes with the bevel gear *H* on the upper end of which is the spur gear *F*. This spur gear engages the rack *E* cut along the inner side of the slide, thus giving the necessary feed movement. The tool block *L* is held in place by screws which pass down through it into steel shoes in the

T-slots *O*. The operation of this mechanism is so apparent that no comment is necessary.

Taper Attachment for a Bevel Pinion

The bevel pinion *X* shown in the lower portion of the illustration Fig. 7 has been bored with a taper hole and the back side faced in a previous operation. A keyway *Y* has also been cut for driving purposes. The equipment shown was designed for a large factory manu-

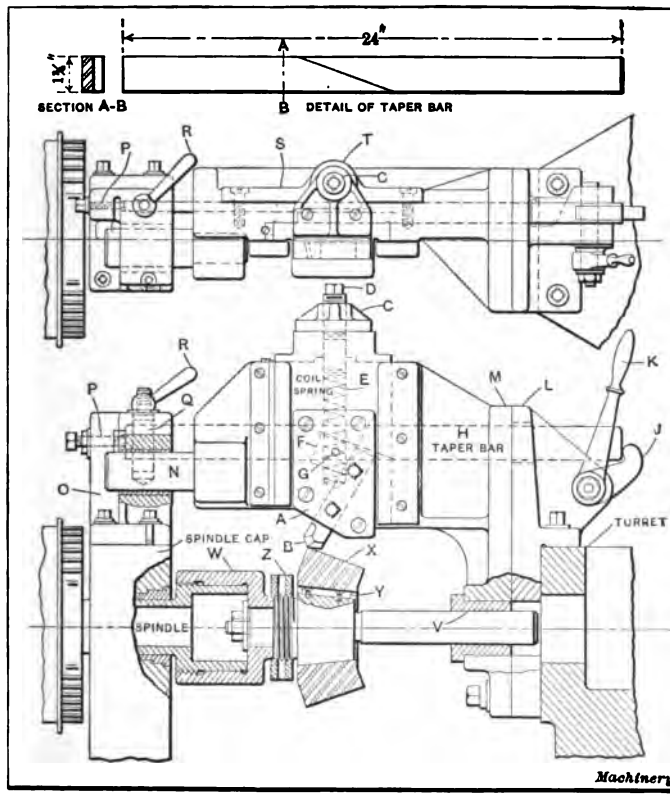

Fig. 7. Taper Attachment for machining a Bevel Pinion

facturing bevel gears and pinions and the taper turning device shown is so arranged that it may be used for a variety of angles. A number of taper bars such as that shown in detail in the upper part of the illustration were made to suit the different conditions.

The spindle nose-piece *W* contains a tool-steel arbor pilot supported at *V* in the fixture bushing. The nut *Z* is simply used to release the work after the machining operation has been performed. A cast-iron adapter *L* is screwed to the turret face, and on this is mounted the body of the fixture *M*. The cutting tool *B* is held in the sliding tool block *A*, which is scraped to a nice sliding fit, and has a taper gib pro-

vided for adjustment. A tool-steel block *F* is pivoted to the back of the slide on the pin *G*, allowing it to adapt itself to the angle cut on the taper bar. Referring to the upper view it may be seen that the plate *S* forms a cover for the open side of the fixture, and that it contains the long boss *T* which holds the spring *E*. This spring thrusts against the end of the screw *D*. The bracket *C* is fastened to

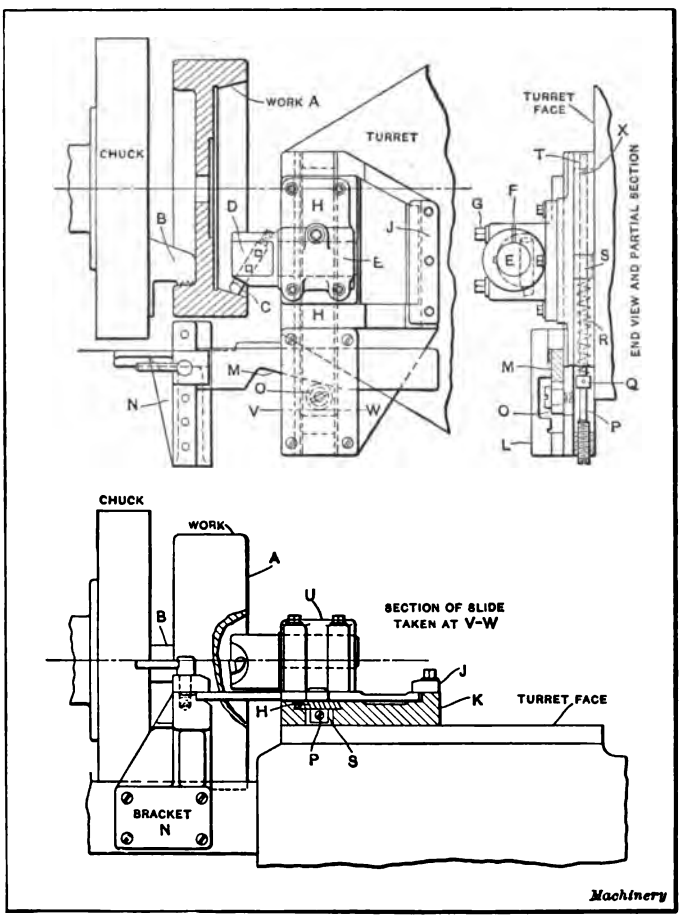

Fig. 8. Exterior and Interior Taper Turning Device

the top of the slide and is tapped out to allow adjustment of the spring by means of the screw. A bracket *O* is fastened to the spindle cap and contains a bronze bushing which acts as a guide for the pilot *N*. The stop screw *P* is used for longitudinal adjustment of the taper bar *H*. The lever *K* is used to force the taper bar forward by means of the rocker *J*. The stud *Q* is slotted to receive the forward end of the taper bar, and when this has been brought forward by the lever

until it strikes the end of the screw *P* the binder lever *R* prevents any backward movement of the bar. The adaptability of this attachment for various tapers is one of the good points of its design and the results obtained by its use are rapid and thoroughly satisfactory.

The device shown in Fig. 8 is adapted for use on a turret lathe hav-

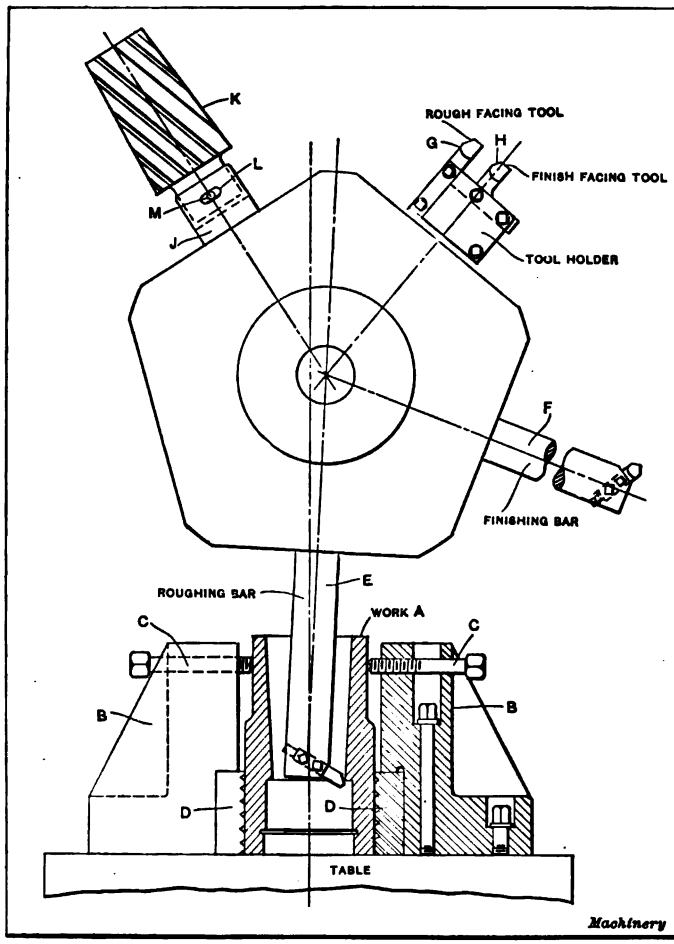

Fig. 9. Attachments for Vertical Turret Lathe and Vertical Boring Mill

ing a flat surface instead of the usual box-shaped construction. A taper bar is used in this instance also, which is cut away at *M* to the desired taper. The attachment may be arranged for either inside or outside tapers, but it is shown in this instance at work on the clutch taper of the piece *A*, this being held by the inside in the chuck jaws *B*. The bed or body of the nxture *K* is fastened to the face of the turret and is dovetailed to receive the slide *H*. A lug *S* on the

under side of this slide receives the thrust of the spring *R* (shown in the end view section). A screw *P* forms an adjustment for the compression of this spring through the collar *Q* which is made removable and can be transferred to the other end of the rod at *X*, when it is desired to use the attachment for outside tapers. The roll *O* is fastened to the slide and its contact with the taper bar produces the required taper. The tool-holder *U* is split along the side at *F* and is bored at *E* to receive the shank of the tool bar *D*. The binder screw *G* is used for clamping. A cast-iron cover plate *L* is fitted so that the pads shown on its under side allow free movement to the passage of the bar. The bracket *N* is fastened to a pad on the side of the bed and is cut away at the top to the proper height so that the taper bar *M* will rest upon it. It is clamped in position by the binder shown, in order to prevent any chance for retrograde action. This attachment has been very successful and is adapted to a wide range of casting work.

Attachments for Vertical Turret Lathe and Vertical Boring Mill

Fig. 9 shows the simplest of conditions which are met with in vertical turret lathe practice, and the method of handling requires no special attachments, the swivel slide of the main head being sufficient to take care of the taper boring, the hole being finally reamed to size by a floating taper reamer. The work *A* is a cast-iron hub and it is held in the special jaws *B*. The work is centered by the steel inserted jaws *D* and the set-screws *C* are simply used to prevent vibration. The roughing bar *E* is first used to generate the taper and it is followed by the finishing bar *F*. Then the rough- and finish-facing tools *G* and *H* face the work, after which the floating taper reamer *K* is used to size the hole. It will be noted that the upper end of the reamer is flattened and enters a slot in the holder *J*, the pin *M* acting as a driver and the slot *L* allowing lateral movement.

Special Gearing used to produce Tapers

The arrangement shown in Fig. 10 is not adapted to all conditions but may be used when the required angle is not too acute to permit the use of the proper gear ratio. A piece of work such as that shown at *A* may be handled to advantage by this method.

The strap *L* is slotted at *M* to receive stud *S*, which acts as a support for the idle spur gear *N*. The lower spur gear *O* is keyed to the shaft, while the upper gear *P* is thrown into use by the clutch mechanism *Q*, by the action of the knurled screw *R*. Obviously the gear ratios between *P* and *O* must be so proportioned that the combination of the horizontal and vertical feed movements will produce the required angle. Attention is called to the fact that the power feed worm *H* is thrown into mesh with the gear *J* on the horizontal feed-screw *G* when the attachment is to be used, but it will be seen that the operation of the feed works is not disturbed by the arrangement shown, the gear *P* running idle unless the clutch is thrown in.

The work *A* in the instance shown is held by straps *C* on the special fixture body *B*. The tool *D* is held in the tool-holder *E* and follows the

angle generated by the gearing. When it is required to produce an angle such that spur gearing cannot be obtained to give the exact taper, the nearest gears obtainable may be used, and the swivel slide of the main head can be set over to compensate for the variation in the gearing.

Fig. 11 shows a method of setting up a vertical turret lathe for a rush job, consisting of a few cast-iron male clutch members shown at

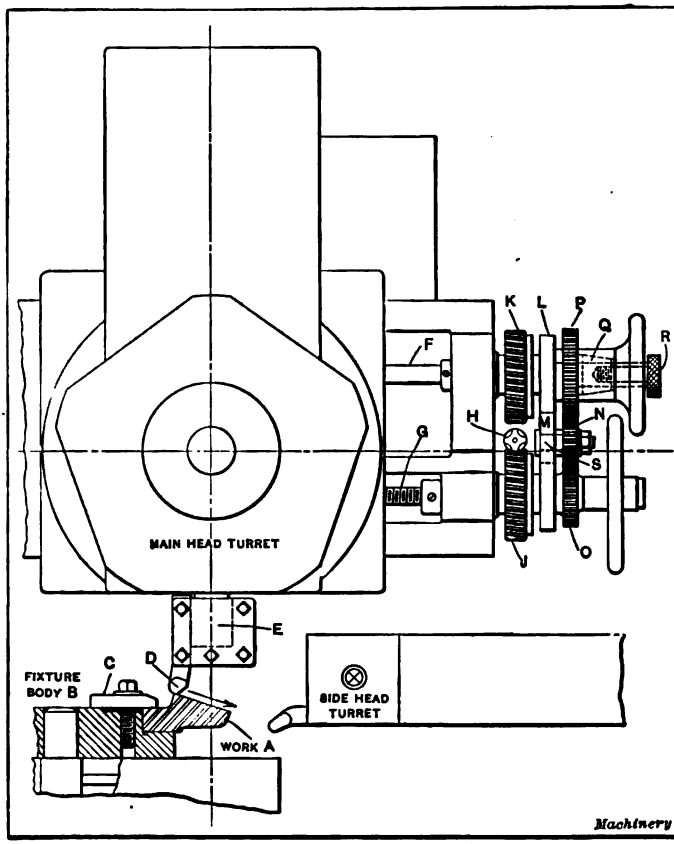

Fig. 10. Illustrating Use of Vertical and Horizontal Feed Combination to produce Tapers

A. The work is held by the jaws *B* on the inside of the rim and the tool *C* is held in the side head turret. A steel plate *F* cut to the required taper is held in the toolpost *G* in the main head turret. A roll holder *D* is fastened in the upper side of the side head turret and the roller *E* comes in contact with the tapered plate and thereby controls the movement of the tool. A flat angular sweep tool *H* is used for finishing the work. In using this arrangement it is only necessary to lock the main head turret in the proper position and

bring the roll *E* against the forming plate. After this the down feed of the side head is thrown in and the roll crowded against the plate by the transverse feed crank on the apron. This method is very good for a short job and the machine may be quickly set up. Several roll holders of this kind will be found useful adjuncts to the tool equipment of the vertical turret lathe.

Another instance of a short rush job is shown in Fig. 12, the work *A* in this instance being held by the inside in the chuck jaws *B*. The

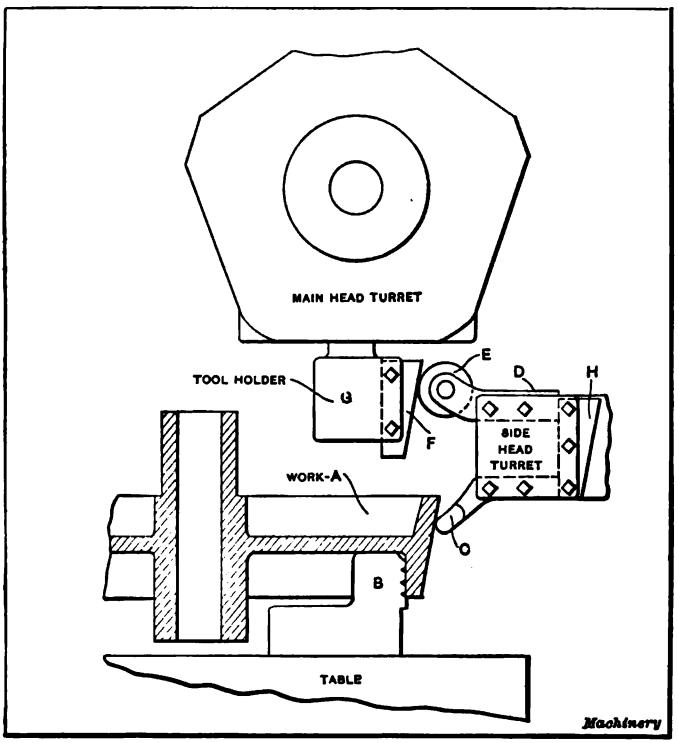

Fig. 11. Makeshift Taper Arrangement for Emergency Vertical Turret Lathe Work

tool *C* is held in the side head turret and is forced down the angle by the contact of the angular plate *D* with the roll *E*. The shank *F* which holds this roll is secured in the tool-holder *G*, in one of the side holes in the main head turret. When this arrangement is used the transverse feed of the side head is thrown in and the plate *D* crowded against the roll by means of the vertical feed crank on the side head apron. It will be readily understood that this arrangement and that shown in Fig. 11 are not to be considered in the light of attachments for taper turning, but they are given as instances of methods which may be used for short jobs, where no taper attachment is available. It is evident that these methods tie up the main head

and prevent its use for cutting purposes while the taper is being formed. As this naturally increases the cutting time necessary to produce the work, the use of such an arrangement is advised only in cases where a few pieces are to be machined.

Angular Taper Attachment for Crowning Pulleys

Fig. 13 is an arrangement which is used where a double angle is required, such as the crowned portion of the pulley *A*. In this case

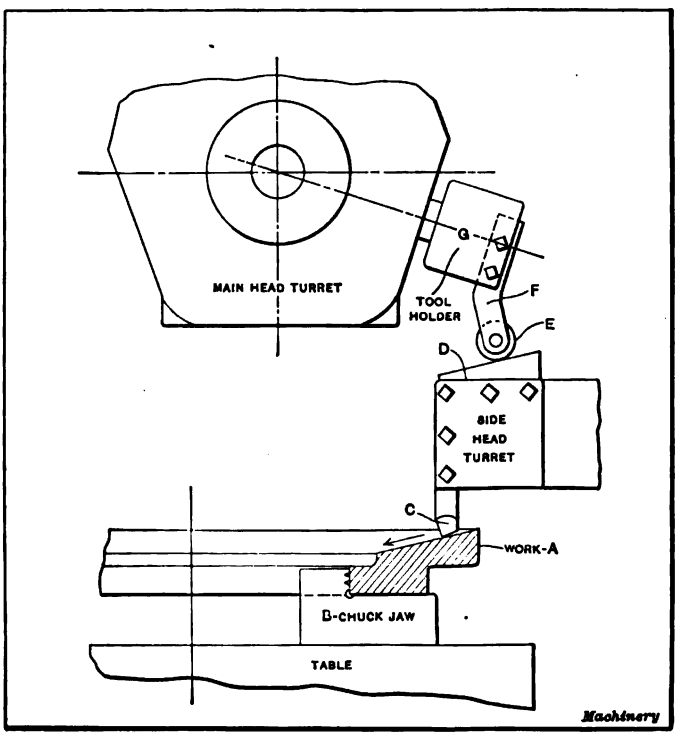

Fig. 12. Emergency Taper Attachment for Vertical Turret Lathe Work

a set of special jaws *B* grip the work on the inside bead in the V-shape part of the jaw. The movement of the tool *C* is controlled by the forming plate *E*, which is cut to produce the angular movement required. This plate is fastened at each end to the bars *F* and *L*, and these bars are, in turn, secured in the upper and lower brackets *K* and *M*. The upper boss *G* is split and the binding screw *H* pinches the bar and holds it in the desired position vertically. The arrangement of the lower bracket is on the same principle. Both the upper and lower brackets are fastened to pads on the bed of the machine. When this attachment is used the T-slot *D* is cut along the entire length of the side head slide so that the T-stud *O* which carries the roller *N*, may be adjusted for various diameters.

Swivel Side Head Forming Attachment for the Vertical Turret Lathe

Fig. 14 represents an attachment made by the Bullard Machine Tool Co., Bridgeport, Conn., for the Bullard turret lathe. The work shown in this instance at *A* is a large bevel gear which is held by the previously bored interior surface in the soft jaws *B*. The tool *C*, in its angular movement is controlled by the inclination of the slot *D* in the

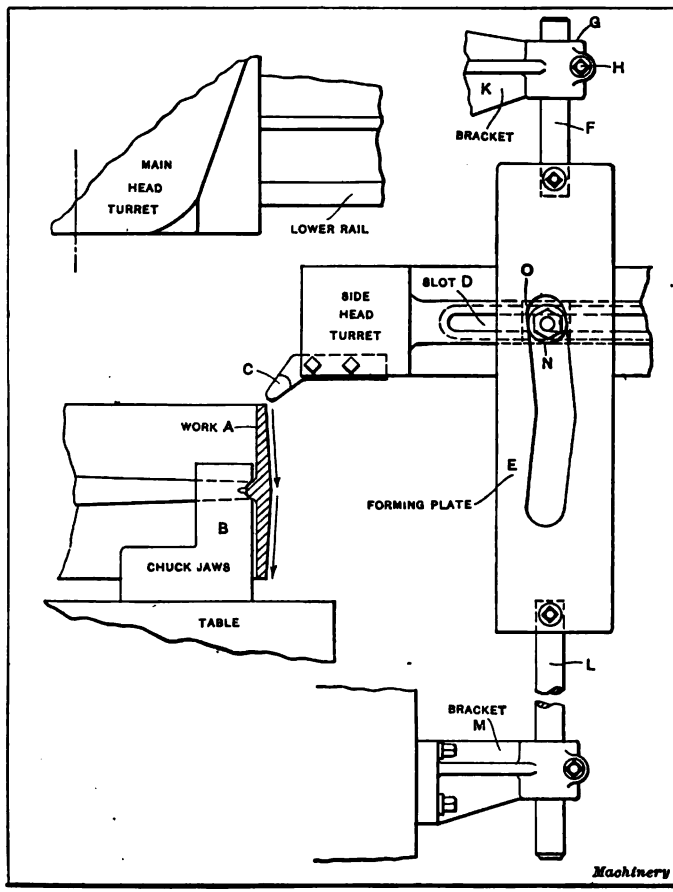

Fig. 13. Taper Attachment for crowning Tools

circular swivel plate. This plate is graduated in degrees around its upper edge so that any angle may be easily obtained. The clamps *F* and *G* secure it in position after the setting has been made. The disk containing the slot is mounted on the plate *H* which is of circular section at the center to allow free access to the roll and block *E*. As in the previous instance a T-slot *L* is cut along the entire length of the side head slide, thereby permitting various diameters to be machined. The bars *O* and *P* are secured in the brackets *K* and *Q* by

the binders *N* and *M*, these brackets being secured to the bed of the machine. This attachment is adapted and may be used for many varieties of work and the results obtained are uniformly satisfactory.

The device shown in Fig. 15 is also made by the Bullard Machine Tool Co., and is adapted to both angular and formed work, and therefore is more comprehensive in its uses than that shown in Fig. 14.

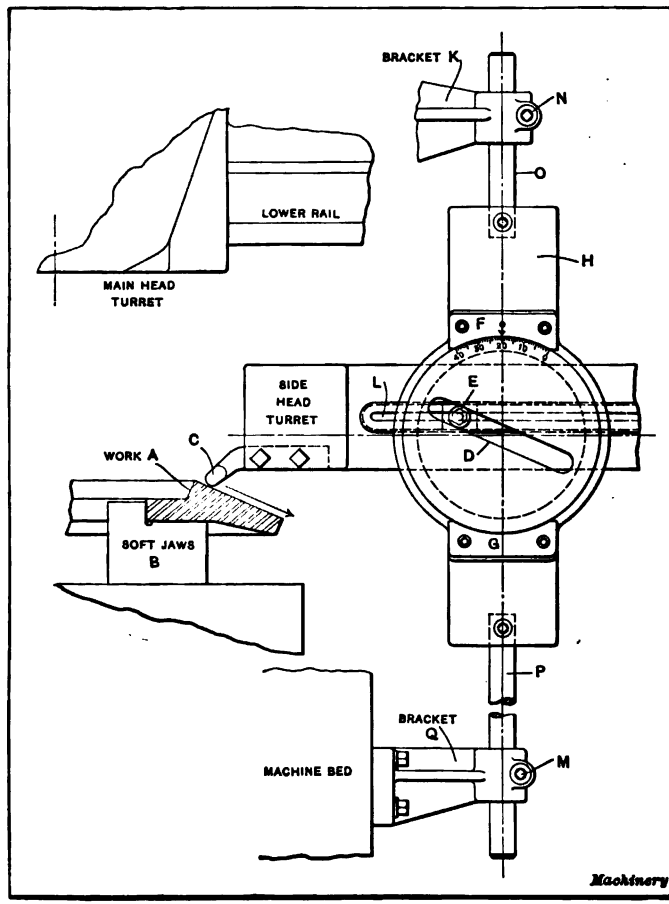

Fig. 14. Vertical Side Head Forming Attachment for the Bullard Vertical Turret Lathe

The piece *A*, held in the soft jaws *B*, is the same as that previously shown. The principles in the design of this attachment are just opposite to those of the other, for in this case the roller *P* is located in the slotted plate and may be quickly removed through either of the end holes *R*, so that the side head may be used for straight work during the same setting of the piece, without much trouble in preparation. The plate *H* is fastened to the rods *F* and S and vertical adjustment

is obtained by sliding up or down. The binding screws *E* and *T* secure it in the desired vertical position. A T-slot *V* is cut along the entire length of the side head slide and a cast adapting plate *O* is secured in it by means of T-bolts. The angular plate *M* is screwed and doweled to the adapter. The brackets *K* and *L* are fastened to the side head

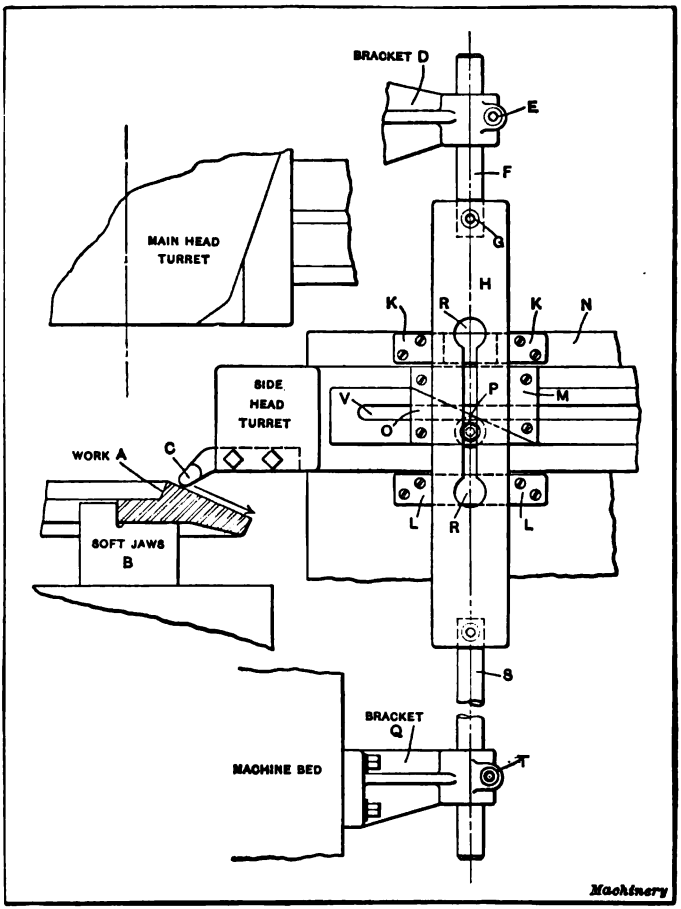

Fig. 15. Taper Turning Attachment for the Bullard Vertical Turret Lathe

down slide and are fitted to the edges of the plate *H*, in order to avoid any bending action which might be produced by the pressure against the roller *P*. The brackets *D* and *Q* are similar to those used in the former case.

Angular Forming Attachment for a Vertical Boring Mill

The work *A* shown in Fig. 16 is a male taper clutch member, and the machine upon which the work is to be done is a vertical boring

mill with a turret head. The piece is held by the inside in the jaws *B* and the tool *C* forms the taper. In order to permit lateral motion a special nut was required for the horizontal feed shaft *K*. This nut is not shown in the illustration but was made somewhat on the principle of a lathe feed shaft nut so that it could be coupled and uncoupled rapidly. A special bracket *D* was fastened to the rail to the left of

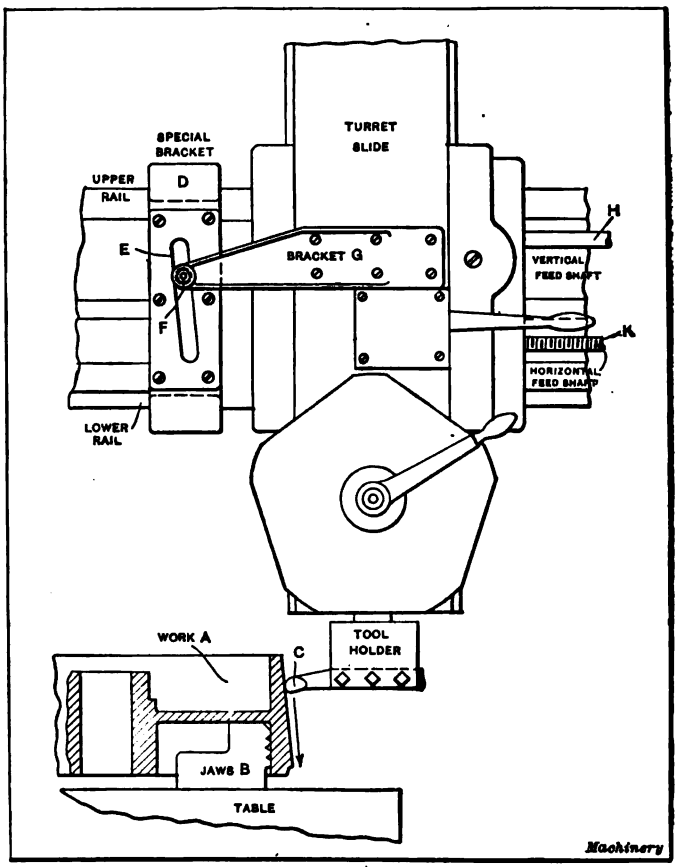

Fig. 16. Angular Forming Attachment for a Vertical Boring Mill

the turret slide and the forming plate *E* was fastened to it. A special bracket *G* was fastened to the turret slide and served as a support for the roller *F*. In use the vertical feed shaft *H* is thrown into gear and the turret allowed to float laterally as controlled by the forming plate *E*. When the other turret tools were to be used, the roller *F* was removed and the horizontal feed shaft nut recoupled. The action of this device was very satisfactory.

A very acute angle was to be produced on the work shown at *A* in Fig. 17 and a vertical boring mill was used to perform the operation

shown. The work is held by the outside by the special jaws *B;* the tool *C* is used to perform the work. Two brackets *D* and *E* are bolted to the rails, one on each side of the turret slide and the cast-iron plate *G* is used to connect them and form a support for the cam plate *F*. A portion of the turret slide is machined off to permit the attachment of the roller bracket *H*. This bracket is slotted with a T-slot and

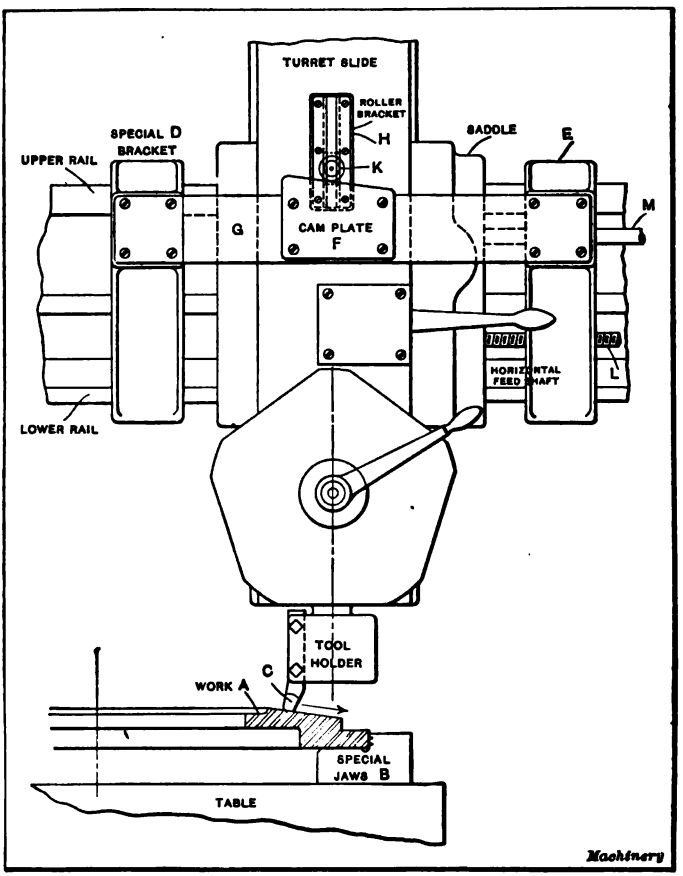

Fig. 17. Taper Attachment for a Vertical Boring Mill

the roller *K* mounted on a T-stud may be readily adjusted in it. In using this attachment it is only necessary to throw in the horizontal feed shaft gears and keep a downward pressure by hand on the cam plate *F*, by means of the handwheel on the end of the shaft *M*.

The various forms of taper attachments and devices which have been mentioned in this chapter cover nearly every variety of work and may be adapted to nearly any form of taper requirements that may be met with in the course of general manufacturing.

CHAPTER II

MACHINING CONVEX AND CONCAVE SURFACES

The machining of convex and concave surfaces is a problem which frequently confronts the mechanic, and its solution may be required under a great variety of conditions. Even the size of the work to be machined is a controlling factor, as it determines to a certain extent the type of machine to be used. For example, the small steel cup washer shown in the upper part of Fig. 1 would naturally be machined on an engine lathe or turret lathe of the horizontal type, while the huge ball pipe joint in the lower part of the illustration would preferably be handled on some type of vertical boring machine. A manufacturing proposition may be necessary where one thousand or more pieces are to be handled, or it may be that only one piece is required. The work may be concave, or convex, in a plane perpendicular to the center of rotation, or it may be parallel with it and either internal or external. As the conditions governing the handling of work of this nature are so varied, and as the pieces themselves are of such widely different forms, it is very evident that we must consider several types of machines to which the forming devices may be attached. The construction of these devices must be adapted to the class of machine on which they are to be used, and this naturally influences the design of the attachments. The reader's attention is called to a few important points along these lines.

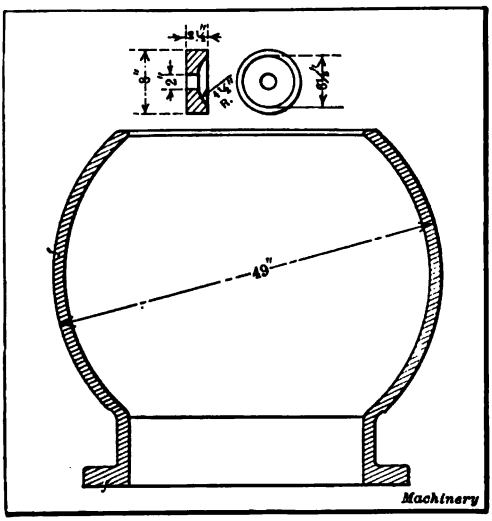

Fig. 1. Cup Washer and Ball Pipe Joint—Examples of Concave and Convex Turning

Important Points in Design

1. Whenever possible the attachment should be so designed that the form will be generated radially, so that the same portion of the tool will do the cutting at all times.

2. Try to use stock sizes of steel for the cutting tools so that replacements can be made easily.

3. See that the tool does not overhang too much, and that it is well supported and rigidly held. Care should also be taken that moving portions of the tool-holder or slide are of generous proportions and possess means of adjustment for wear.

4. Generate the curve by means of the machine alone, whenever possible, so that errors in the contour may not be occasioned by the failure of the operator to keep a certain roll or stud in contact with the forming plate.

5. When the attachment is of the type requiring the use of a roll and forming plate, it is essential to so arrange the plate that it will act as a guard against the tool being forced away from the work. That is, the action of the roll against the plate should be in the direction tending to carry the tool into the work, so that the thrust of the cut will always assist in keeping a positive contact between the roll and the plate. Counterweights or springs should also be used to obviate any tendency to draw in.

6. Economy in operating expense and the first cost of the attachment should also be considered, while the difference in workmen's rating is also a factor which should not be overlooked.

Radius Turning on the Engine Lathe

When concave or convex turning or boring is required on only one or two pieces, or, in cases where it is not practicable to combine the radial work with other operations, the engine lathe may be adapted to a great variety of conditions. In manufacturing, it may occasionally be used to advantage, especially in cases when the length of time required to do work is sufficient to permit one man to run two machines.

Fig. 2 shows the simplest kind of a forming attachment for convex work, which is adapted to the engine lathe. The work *A* is held by the inside in the chuck jaws *M*. The bracket *H* is screwed to the top of the cross-slide and carries, at its outer end, the tool-steel hardened and ground roller *K*, held in place by the screw *L*. The tailstock spindle *D* receives the holder *E* in which the plate *G* is inserted and secured by the two screws *F*. This plate is formed to the proper radius and is of tool steel unhardened. The cutting tool *B* is held in place in the regular toolpost *C*. The form of the cutting end of this is important as it must be formed to a perfect radius, in order that the cutting action may be uniform. In operating this attachment, the cross feed-screw is thrown into engagement, and the operator is required to force the roll *K* against the forming plate by means of the handwheel controlling the longitudinal feed of the carriage. An attachment of this sort requires the entire attention of the operator and, therefore, variations are liable to occur in the contour of the work, due to imperfect contact between the roll and plate; hence it is a very poor attachment to use if there are many pieces to be machined.

Piston Crowning Attachment for the Lathe

The arrangement shown in Fig. 3 was used for manufacturing in large quantities, and four lathes were equipped in this manner and required the services of two men to operate them. The piston *A* was located on a special draw-back chuck, on the steel locating ring *D*, and was drawn back firmly by the rod *C* acting on the pin *B* through the wrist-pin holes. A cast-iron bracket *E* is bolted onto the carriage of

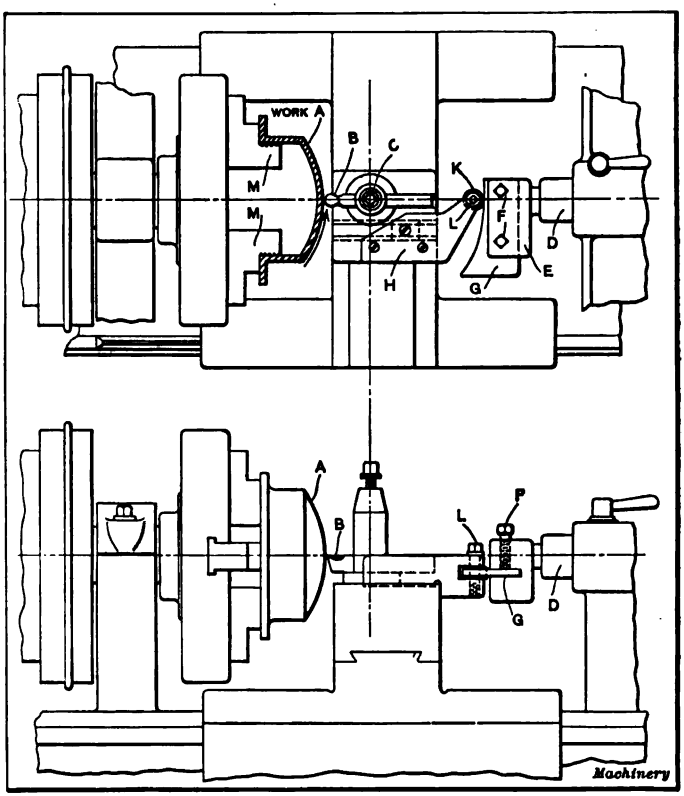

Fig. 2. Simple Attachment for Convex Turning in Engine Lathe

the lathe and is slotted at *G*. A cast-steel bracket *H* terminates at its upper end in the tool-block *K* which is dovetailed at *M* as shown in the plan view. The stud *F* is tee-shaped at its lower end to fit the slot in the bracket *E*. A steel block is screwed to the top of the cross-slide *P*, and is shouldered at *N* to fit the upper block in which the dovetailed tool-block *K* slides. The screw *O* simply holds the units together. A steel plate *Q* contains the two screws *R* and *S* which securely hold the tool *L*. In operating this device, the cross feed-screw is simply thrown into engagement and its forward action causes the tool to swing radially at the desired distance from the center *F*,

thus developing a spherical surface. This device was comparatively inexpensive and the results obtained by its use were very satisfactory.

Concave Turning with a Compound Rest

A very simple device which may be used when one or two pieces only are required is shown in Fig. 4, but the radius which can be generated by this method is limited by the size of the compound rest.

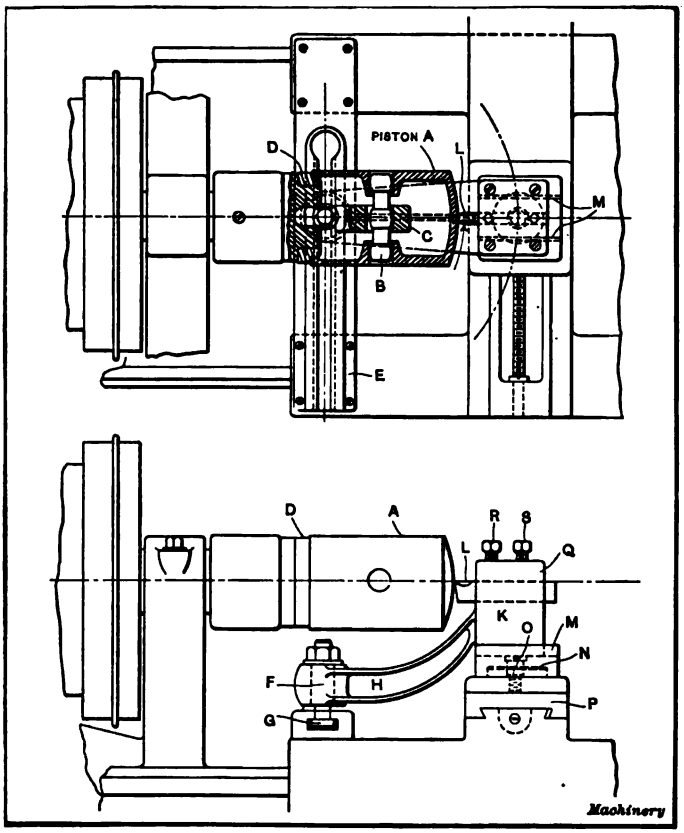

Fig. 3. Piston Crowning Attachment for the Lathe

The work *A* is held by the outside in chuck jaws, and the tool *C* generates a radius equal to the distance from the end of the tool to the center of the swivel. The socket *G* is placed in the tailstock spindle and the overhanging end contains the round head pin *H*. The bar *D* is cup-shaped at *E* and *F* and bears against the end of the compound rest screw at *E*, while the other end engages the button at *F*. In using this arrangement, the holding-down gibs or straps of the compound rest swivel are set up to produce considerable friction, and the tailstock spindle is fed forward by hand, thus causing the com-

pound rest to swing on its own center, thereby generating the desired radius. It is obvious that the carriage gibs must be tightened to prevent any longitudinal movement.

Radius Bar for Concave Turning

A very simple arrangement for the engine lathe is shown in Fig. 5. The work *A* is held by the outside in chuck jaws and the round nose

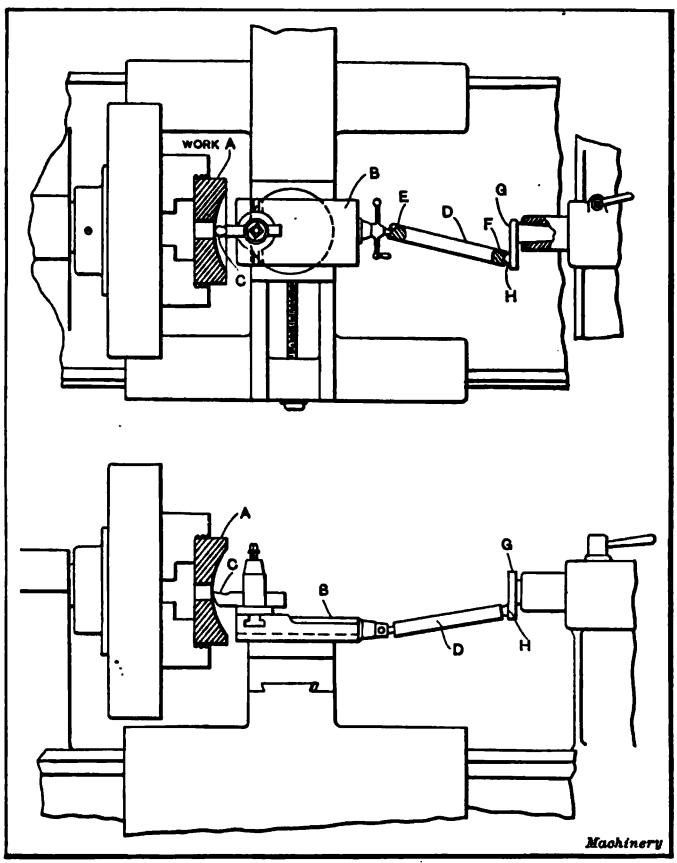

Fig. 4. Concave Turning with Compound Rest

tool *B* is used to generate the concave surface. The tool is held in the ordinary manner in the toolpost *C* on the cross-slide of the lathe. A slotted holder *K* is tapered on its rear end to fit the tailstock spindle *B* and is slotted to receive the flat steel radius-bar *G* which is held in position by means of the shoulder screw *H*. The stud *F* enters the tool slot of the cross-slide and serves as a pivot for the forward end of the radius-bar. This bar is made of the correct length to generate the desired radius. As in a previous instance, the cutting

end of the tool *B* must be ground to a perfect radius. The arrangement shown here is a very simple one and may be used for various pieces of work by the substitution of a bar of the proper radius.

Pulley Crowning Attachment for the Engine Lathe

Fig. 6 illustrates an arrangement that was applied to an old-style Pratt & Whitney lathe which had, at one time, been equipped with a

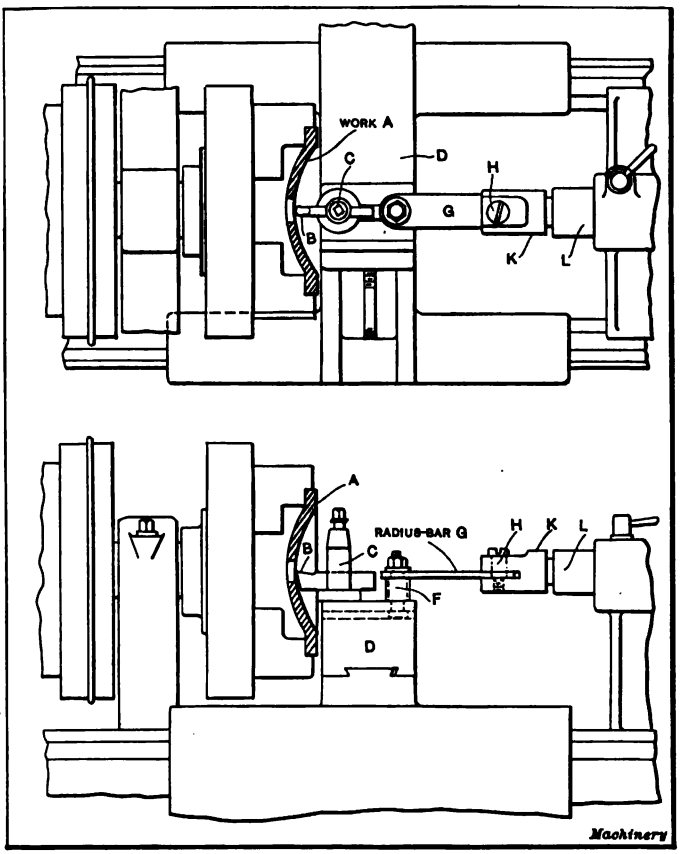

Fig. 5. Radius-bar Type of Concave Turning Attachment

taper attachment. The arrangement shown was specially designed for crowning pulleys which previously had been "chucked," faced and rough-turned straight on the periphery. A keyway had also been cut through the hub. A special arbor *D* was held on centers in a lathe, the dog *E* acting as a driver in the special faceplate *F*. The pulleys were put on the arbor until the face of the hub came up against the shoulder *H*, the spacer *J* being interposed between the two hubs. The cast-iron driving plate *K* was then put on, followed by the washer *M*. The nut *L* was then used to tighten the pieces in position. The driv-

ing bar *G* was used in order to prevent vibration which would otherwise be troublesome due to the thin flange of the pulleys. The two round-nosed tools *B* were mounted on the tool-slide *C* and held in the ordinary manner. A steel plate *Y* was bolted to the end of the slide and overhung sufficiently to permit the bar *X* to pass through it. This bar passed completely through the carriage and was a sliding fit in

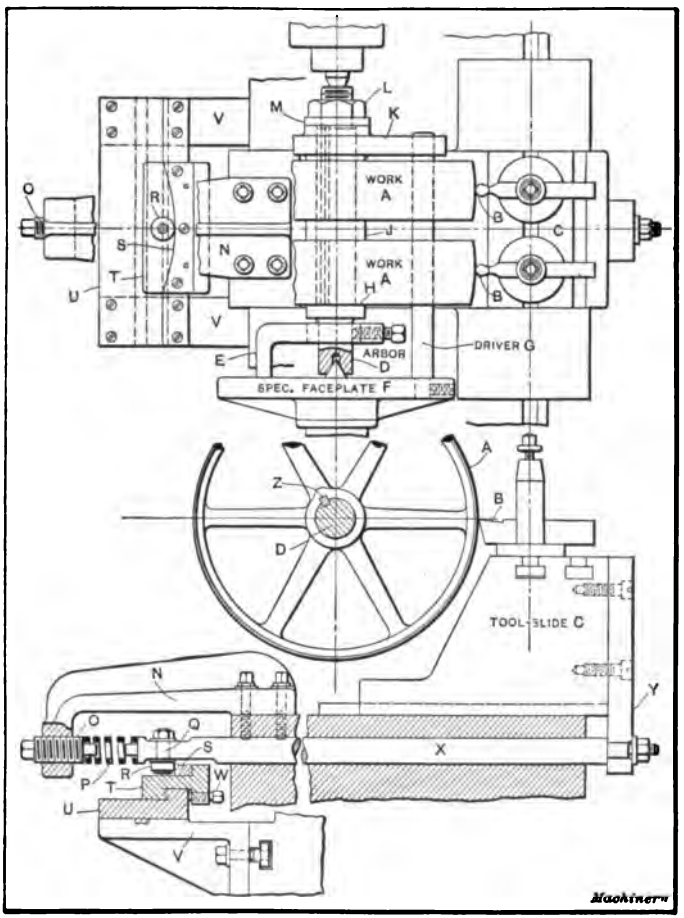

Fig. 6. Pulley Crowning Attachment for Engine Lathe

it. The stud *Q* passed through the bar and formed a bearing for the roller *R*. The cast-iron bracket *N* was fastened to the rear of the carriage and was tapped at its outer end to receive the screw *O*, which was used for adjusting the compression of the spring *P*. This spring was of square section ¼ inch in size and served to keep the roll in contact with the cam-plate *S*. Two brackets *V* and the plate *U* were a part of the taper attachment with which the lathe was orig-

inally equipped. The dovetail plate *T* served as an adjustable support for the cam-plate *S* and it was held in its proper location by the screws *W*. The upper view in the illustration is partially broken away to show the roll *R* in position against the cam-plate. The operation of this attachment is obvious and it is only necessary to state that its action was very satisfactory.

Fig. 7 shows a rather peculiar attachment for turning the convex surface on the cast-iron head-piece shown at *A*. The device is applied

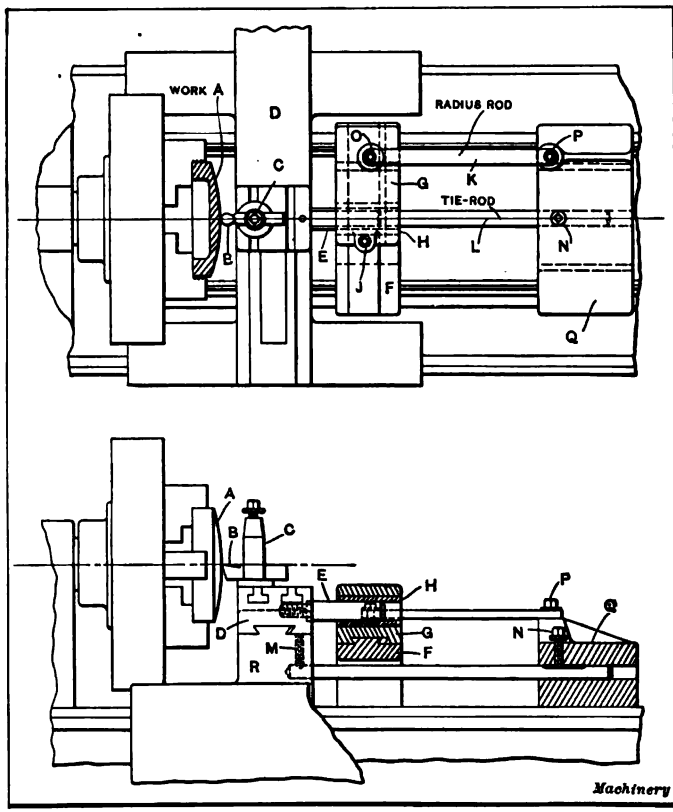

Fig. 7. Convex Turning Attachment of Radius-bar Type

to the engine lathe, and its construction is such that, by the substitution of various lengths of radius-rods, it may be used for an infinite number of radii. The cutting tool *B* is held in the toolpost *C* in the ordinary manner and the longitudinal feed-screw is left free so that the carriage *R* may be perfectly independent. The bracket *F* is secured to the inner ways of the lathe so that it is absolutely prevented from moving. This bracket is dovetailed along its upper face and the slide *G* is mounted upon it. A tool-steel stud *E* is screwed into the side of the cross-slide and enters the bushing *H* which is

contained in the bracket slide *G*. This bushing is eccentric and is split along one side thus permitting a slight adjustment to compensate for wear. The binding screw *J* holds it rigidly after setting. The tie-rod *L* connects the carriage *R* with a special bracket *Q* at the rear end of the lathe, this bracket taking the place of the regular tailstock, and being gibbed to the ways in such a manner that it is

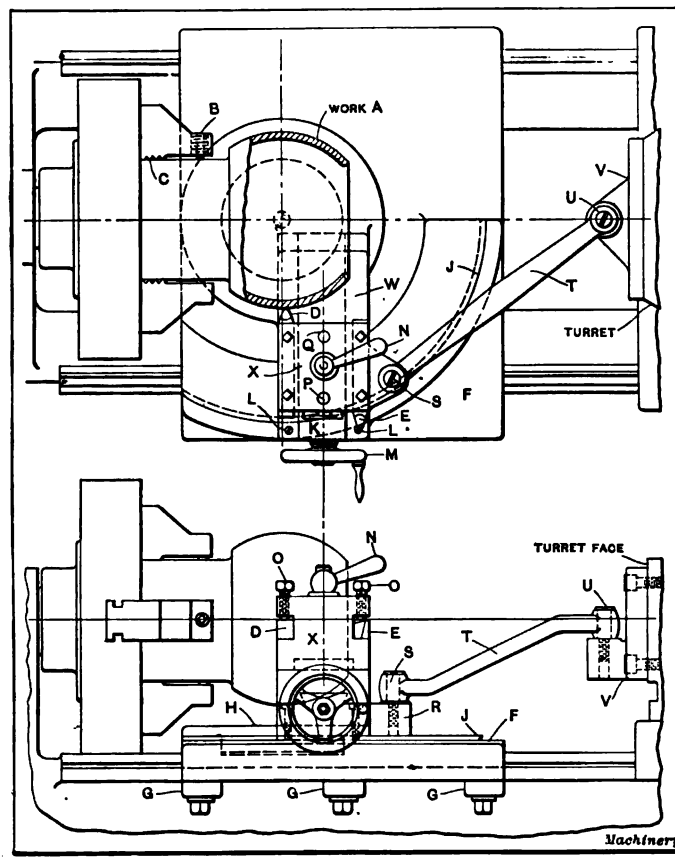

Fig. 8. Spherical Turning Device for Horizontal Turret Lathe

free to slide longitudinally. The tie-rod is held in place by the screws *N* and *M*. The radius-rod *K* is made from a piece of flat steel and swings on the two screws *O* and *P*, located in the bracket slide and the tailstock substitute respectively. In the operation of this mechanism, the cross feed-screw is thrown into mesh and the slide *D* moves forward carrying with it the bracket slide *G* to which the radius-rod is attached. As the bracket *F* cannot move longitudinally, it is evident that the tailstock substitute *Q* will be forced backward by the

radius-rod and will carry with it the entire carriage and cross-slide, thereby generating the desired radius.

Ball-turning Device for the Horizontal Turret Lathe

We now come to a somewhat more pretentious device designed for the horizontal turret lathe for the purpose of generating the spherical portion of the steel pipe joint shown at *A* in Fig. 8. This work is held in chuck jaws at *C*, the supplementary screws *B* being used in the outer ends of the jaws to assist in supporting the work. The regular turret lathe cross-slide and carriage are removed and the special slide *F* is substituted. It is gibbed firmly to the ways in the desired position by the gibs *G*. Directly under the center line of the spindle, a large circular recess is bored to receive the swivel *H*, and circular rim *J* is dovetailed so that the outer end of the swivel may be gibbed at *K* to insure rigidity. The two screws *L* hold the gib. The slide *W* is dovetailed and has an adjustment for diameters, controlled by the handwheel *M*. The roughing and finishing tools *D* and *E* are held in the indexing toolpost *X*, the tools being secured by the screws *O*. The index location is insured by means of the pin *P* entering a hole directly underneath it in the slide, and the other index position is determined by the hole *Q*. The binder *N* locks it rigidly. At the right of the swivel the lug *R* is built out to receive the pivot screw *S*, on which the forward end of the radius-arm *T* is fastened. A bracket *V* is bolted to the face of the turret and carries the screw *U* which supports the other end of the radius-arm.

In the operation of this device, the turret longitudinal feed is used while the roughing tool *D* removes the scale from the casting. The toolpost is then indexed and the finishing tool *E* completes the work. This attachment gave very good results and was satisfactory in every respect. There are several points in the construction of this device to which attention should be directed. One of the points is the turret toolpost by means of which the tools always remain set, so that the diameters are easily held to size. Another point is the dovetail gibbing of the outer portion of the swivel. This method does away with all possibility of chatter, providing the gib is kept tight. Another advantage is the adjustment for various diameters by means of the slide *W* which is mounted on the swivel.

Turret Lathe Attachment for Crowning a Piston Head

The attachment in Fig. 9 is part of an equipment of tools for finishing the piston *A*, the work being held by the inside on a special chuck *B*, which is screwed onto the end of the spindle. There are turning tools fastened to the turret which are in action simultaneously with the attachment shown. These are not shown in the illustration, as they have nothing to do with the radius attachment. A special steel cross-slide *C* is mounted on the carriage in place of the regular slide, and the overhanging portion *G* carries a tool-block *M* in which the grooving tools for the piston are mounted. A special bracket *D* is

firmly gibbed to the ways and secured by the screws *L*. The tool-steel forming plates *E* and *F* are screwed to this bracket and doweled in position. The plate *F* also acts as a strap for the overhanging portion of the cross-slide at *H*. A hardened and ground tool-steel roller *J* is pivoted on the stud *K*, and controls the form of the crown by its contact with the plate *F*. The other plate *E* only acts as a

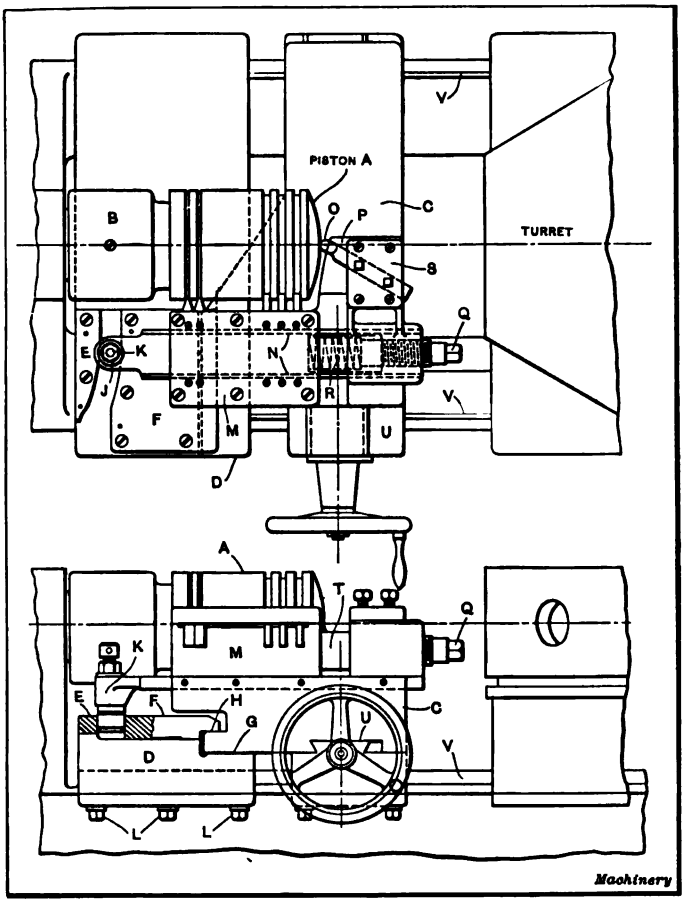

Fig. 9. Turret Lathe Piston Crowning Attachment

guard. The radius forming slide is dovetailed at *N* and passes through under the tool-block. It carries a tool *O* mounted in the tool-holder *S*. A supporting pad *P* is provided on the cross-slide directly under the tool-holder and serves to prevent vibration. A heavy coil spring *R* is used to insure proper contact of the roll with the cam-plate. The necessary adjustment is obtained by means of the screw *Q*. A brass tube *T* protects the spring from chips and dirt which might otherwise impair its action.

This attachment was built for a large manufacturing plant in the East, and proved very satisfactory. It is designed so that all the tools can work at the same time. In building the attachment, it was found necessary to fit the dovetail slides and other moving portions, after the tool-blocks were put in place, and the tools clamped in position. This was unavoidable because of the clamping strains, as these

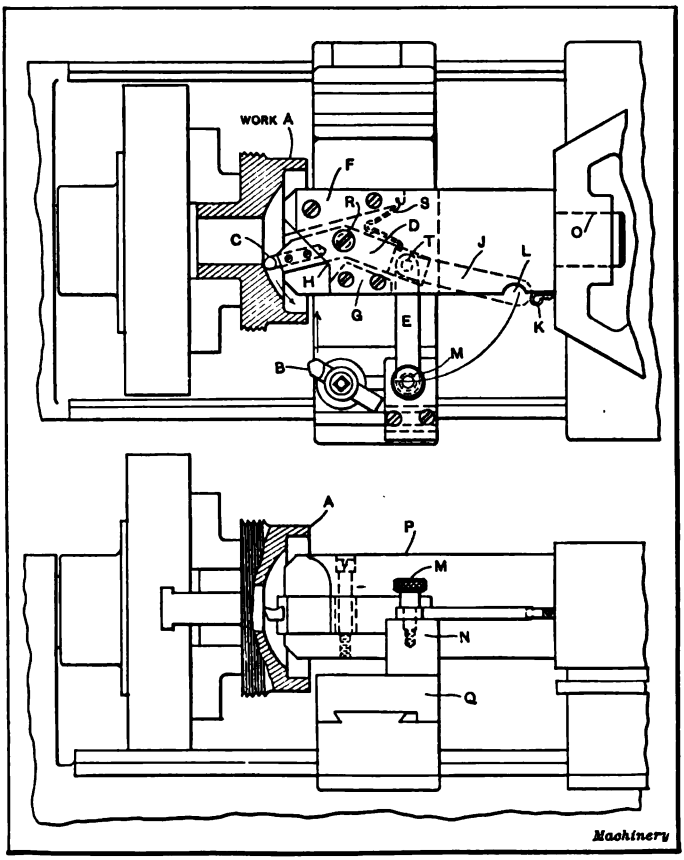

Fig. 10. Turret Lathe Attachment for turning Concave Seat

caused a certain amount of distortion, making it necessary to do the fitting after the tool-blocks were in position.

Radius Boring Attachment for a Horizontal Turret Lathe

The device for generating the internal radial seat in the brass casting *A*, shown in Fig. 10, is somewhat out of the ordinary, and in addition to this, it is comparatively inexpensive. Furthermore, it is practically a self-contained unit, and requires no special fitting or attachments to the machine.

The steel bar *P* is held in the turret by the shank *O* and is secured in place by the turret binder. The bar is slotted completely through to receive the swivel arm *D* which is a machinery steel forging ground on two sides to fit the slot. The forward end of this swivel arm carries the tool *C* which is set at the proper distance from the screw *R* to produce the desired radius. At the end of the bar, a mill cut is made at *H* in order to permit access to the screws which hold the tool in position. The steel filler blocks *F* and *G* are put in to give additional

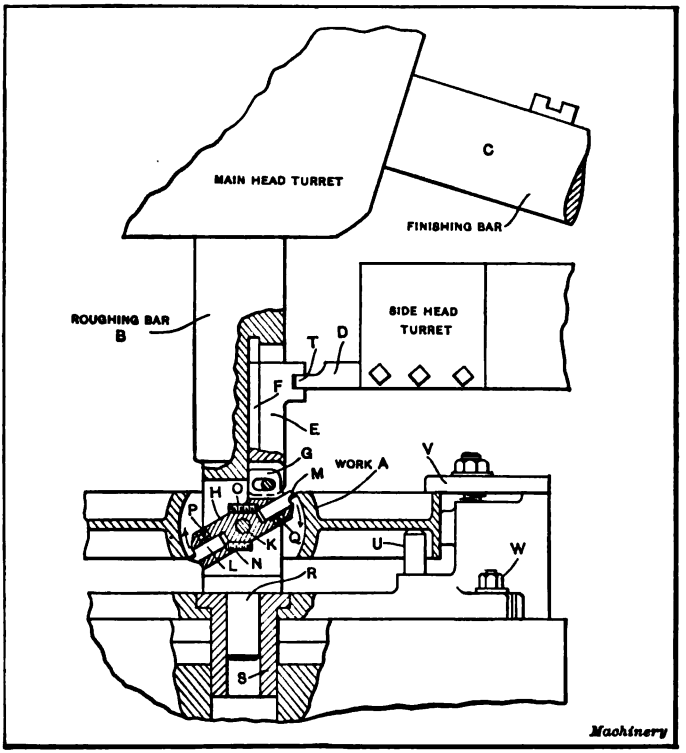

Fig. 11. Radius Boring-bar for Vertical Turret Lathe

rigidity to the end of the bar. The flat spring *S* is simply used to prevent back-lash in the swivel arm. The operating link *E* enters a slot in the end of the swivel arm and is held by the pin *T*. A special steel block *N* is fastened to the cross-slide and the knurled screw-pin *M* couples the end of the link to the slide. The tool *B* is used in connection with the attachment for facing the end of the work.

In operation, the cross-slide feed-screw is engaged and the radius nicely generated by the radial action of the arm. As soon as this operation has been completed, the knurled screw *M* is rapidly removed and the link *E*, swung over into the slot *J* where it is held by the flat spring *K*. The cut *L* allows the fingers to grasp the link when the

radial attachment is again put into use. This attachment has many good points, the only serious draw-back being that there is a slight tendency to chatter when the cut is excessive.

Radius Boring Bar for the Vertical Turret Lathe

The device shown in Fig. 11 was designed for use on the vertical turret lathe, and was used in connection with other tools in the main and side heads for the purpose of boring the radial portions of the automobile crank-case cover bracket shown at *A* in the illustration.

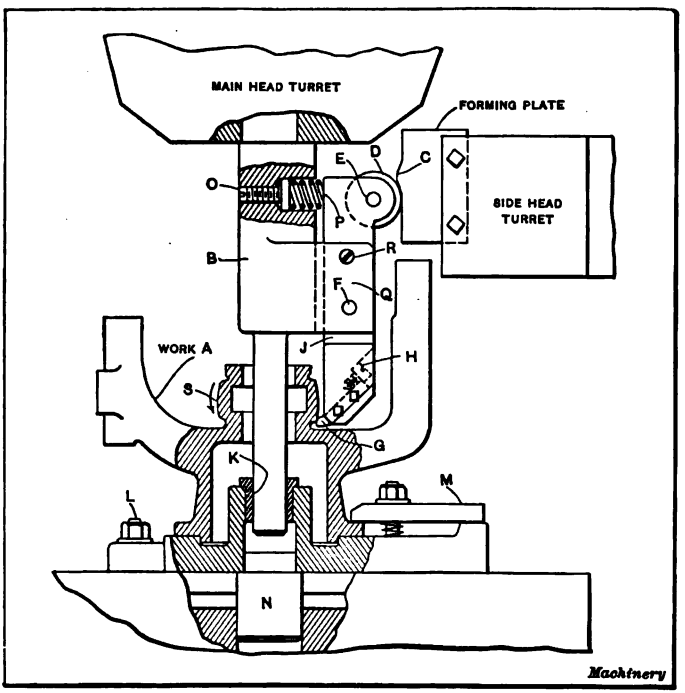

Fig. 12. Attachment for Convex Turning in Vertical Turret Lathe

The work is held on a locating fixture upon three pins *U* and is clamped by means of the straps *V*. Only a part of the work is shown, as the piece is somewhat large, and the other portions have nothing to do with the radial boring. The fixture is held to the table by three tee-bolts *W* and it is centered by the steel bushing *S*, which also acts as a guide for the stem of the boring-bar *R*. This bar is slotted out at its lower end to receive the swivel block *H*, which carries the tools *L* and *M* for rough-boring the radius. The block swings on the pin *K*, when forced to do so by the downward action of the operating arm *E*. The two cutting tools are backed up and adjusted by means of the screws *N* and *O*, and they are held firmly in position by the set-screws *P* and *Q*. The bar *B* is slotted out to receive the tongue *F* on the

operating arm, and the lower end of this arm contains a pin which works in a slot at *G* in the upper portion of the swivel tool-block. The steel piece *D* is held in the side head turret and engages a groove in the upper part of the operating arm.

The finishing bar *C* is of the same general construction as the roughing bar except that only one tool is used for finishing, instead of the two shown in the roughing bar. It is well to note that the use of two tools in roughing practically reduces the roughing time one-half, it being only necessary to cut half way with each tool, as one comes

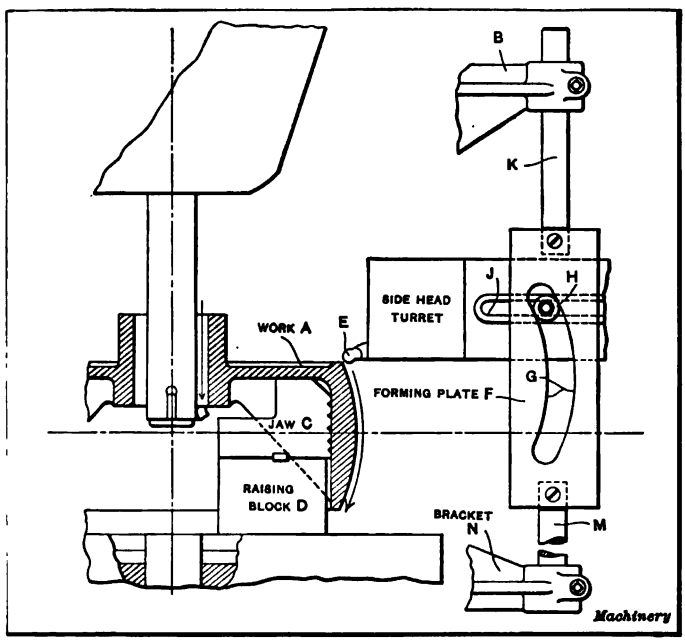

Fig. 13. Device for crowning Pulleys in Vertical Turret Lathe

up from the bottom while the other is coming down, so that the two cuts meet at the center. In operation, the down feed of the side-head turret is started, thus providing the necessary power for operating the device. This scheme gave very satisfactory results as far as accuracy is concerned, but as the mechanism was confined in a small space, the size of the tools could not be made large enough to properly conduct away the heat generated in boring.

Convex Turning Device for a Difficult Piece of Work

Fig. 12 shows a device for convex turning. The jack-shaft tube bracket *A* has been previously machined at its lower end and is located for this setting by the finished surfaces. A special fixture is bolted to the table of the vertical turret lathe, by the three tee-bolts *L*, and it is firmly secured by the straps *M*. The stud *N* serves to center

the fixture on the table, while the bushing *K* acts as a guide for the end of the bar. The radial surface *S* is to be machined at this setting, and it will be noted that it is somewhat confined. The generating bar *B* is a 0.40 carbon steel forging, and the piloted end is carbonized, hardened and ground to a running fit in the bushing *K*. The projecting portion *Q* of the bar is of rectangular section and is slotted to receive the swinging arm *J*, which is pivoted on the pin *F*. This pin is equi-distant from the end of the cutting tool *G* and the center of the pin *E*. A hardened and ground tool-steel roller *D* revolves upon the

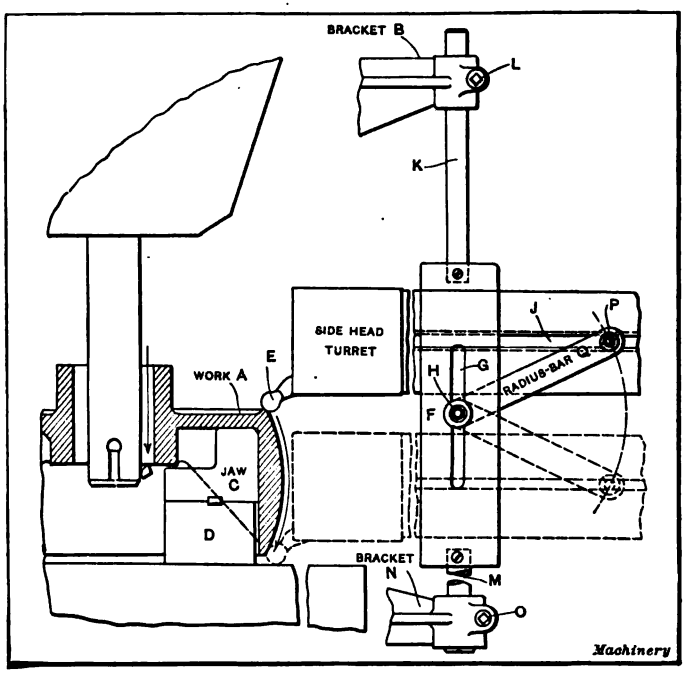

Fig. 14. Another Pulley Crowning Attachment

latter, and is kept in contact with the forming plate *C* by means of the spring *P*, which is very stiff. Adjustment is provided through the screw *O*.

In operating this device, the turret down feed is used and the side-head turret is locked in the proper relation to the cutting tool, to produce the radius at the correct height on the casting. For the finishing cut, the roughing tool *G* is removed and a finishing tool substituted. A special screw *H*, having a large head against which the ends of the tools bear, makes this comparatively easy. The work can be turned closer to size if two roughing tools and a finisher are used, leaving only about 0.010 inch for the final cut. A defect in this fixture is that the thrust of the cut has a tendency to force the roll away from the cam-plate, and the action of the spring is sometimes insufficient to en-

tirely overcome this. Had it been possible to design this attachment in such a way that the thrust of the cut would simply hold the roll more firmly against the forming plate, its action would have been more positive. The results obtained were sufficiently close, however, to conform to the required limits of accuracy, and it may therefore be stated that its work was satisfactory.

Convex Forming Attachment for the Vertical Turret Lathe

A simple arrangement for the vertical turret lathe which permits the simultaneous use of both the main head and side heads, is shown

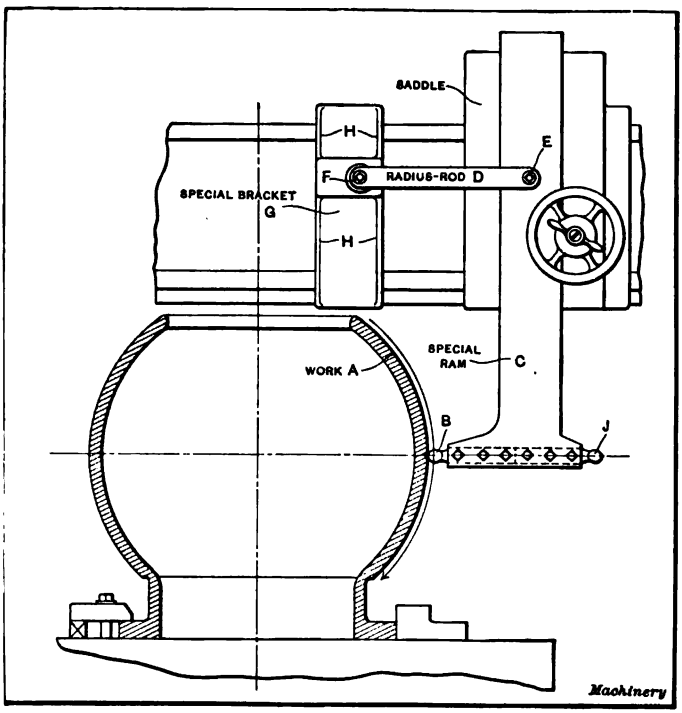

Fig. 15. Spherical Turning Attachment for Vertical Boring Mill

in Fig. 13. The work *A* is a tractor pulley of large size. This is held by the inside, in the jaws *C* which are mounted on the raising blocks *D*. The boring-bar shown may be used if desired, while the radius turning is taking place, as the radius attachment does not interfere in any way with the movements of the main head. The construction of this device is extremely simple and the results obtained by its use are very satisfactory. The upper and lower brackets *B* and *N* are attached to the bed of the machine and carry the rods *K* and *M*, which support the forming plate *F*. This plate is cut at *G* to the desired radius, and the tool-steel roller *H* travels along the slot and forces the tool *E*, which is held in the side-head turret, to take a similar path.

thereby producing the convex surface on the rim of the pulley. A tee-slot *J* is cut along the entire length of the side-head slide, and the roll *H* is fastened to a special bolt which can be adjusted to any position in the slot. The forming plate is also adjustable vertically, by sliding the rods up or down in the brackets.

Side-head Attachment using a Radius Bar

Another method for crowning the outside of a tractor pulley is shown in Fig. 14, a radius-bar being used in this case to generate the desired

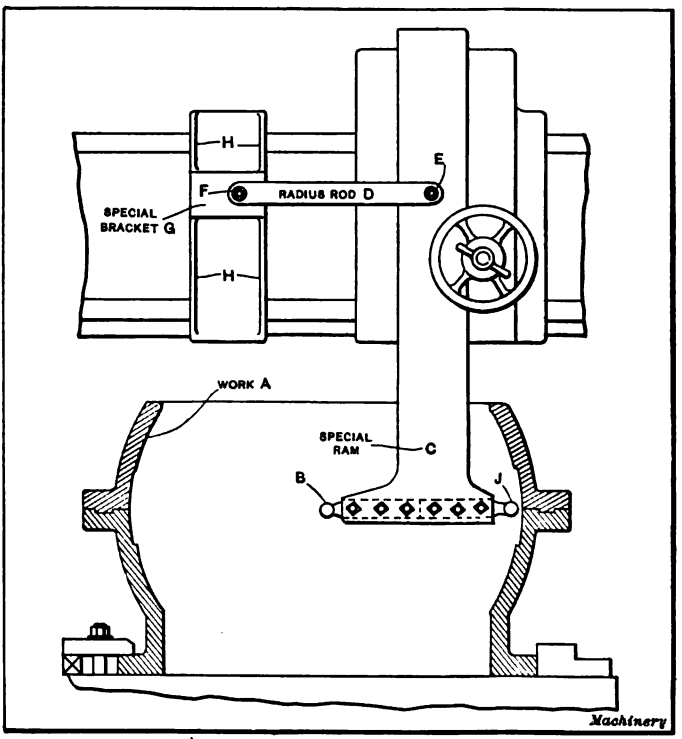

Fig. 16. Attachment shown in Fig. 15, used for Internal Work

curve. The work *A* is held, as in the previous instance, by the jaws *C* on the raising blocks *D*. The same brackets are also employed, but the plate *F* is not used for forming. It is slotted at *G* for adjustment only and a special screw or stud *H* is used in the slot as a pivot for the radius-bar *Q*. A tee-slot *J* is cut along the entire length of the side-head slide and receives a special stud *P*, to which the other end of the radius-bar is fastened. The down feed of the side-head is thrown into engagement when operating the device, and the tool *E* naturally follows the radial path controlled by the length of the radius-bar. This device is simple and good and only requires extra radius-bars in order to handle a great variety of work.

Vertical Boring Mill Attachment for Spherical Turning

The male member of a very large ball-and-socket pipe joint is shown at *A* in Fig. 15. The spherical portion, which is to be machined, has an outside diameter of forty-nine inches. This member fits the female portion shown in Fig. 16, and the attachments used for boring and turning are the same, although the locations and the tools are different. A special bracket *G* is mounted on the rail and is gibbed at the rear

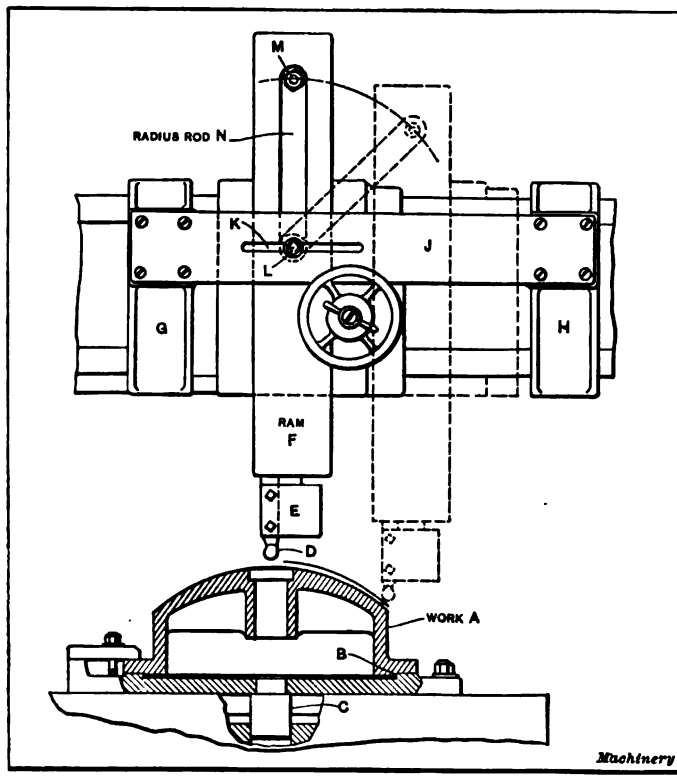

Fig. 17. Convex Turning in a Horizontal Plane

so that it can be adjusted easily. It is well gibbed at *H* to insure rigidity. The special ram *C* was made in the form shown, its lower end acting as a tool-holder for the tools *B* and *J;* the former is used for the outside turning and the latter for the inside boring. The ram itself is a steel casting of extra-heavy section on account of the excessive overhang required. The radius-rod *D* was fastened at the two ends by the screws *F* and *E*, and was made of the proper length to give the correct radius. A special arrangement, not shown in the illustration, permitted a side floating action to the saddle along the rail, when the down feed was engaged.

For handling the socket portion of the joint shown (Fig. 16), the entire mechanism was moved over on the rail far enough to bring the tools in the desired position for boring, the tool *J* being used for this purpose.

Attachment for Convex Turning in a Horizontal Plane

The work *A* shown in Fig. 17 is a steel casting which has been previously machined at *B*. It is held on a fixture (located centrally on the table by the plug *C*) and clamped down by the three clamps around the flange. Two brackets *G* and *H* are mounted on the rail and serve

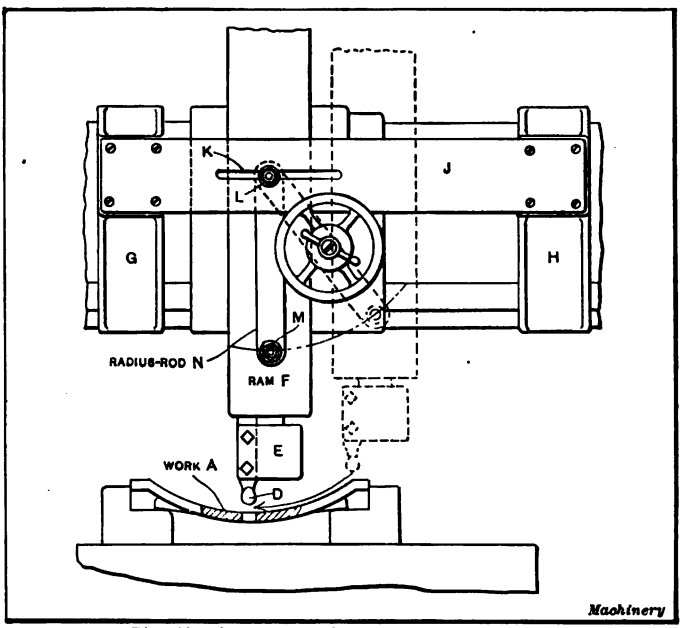

Fig. 18. Concave Turning in a Horizontal Plane

to carry the supporting plate *J*. As these brackets necessarily extend some distance in front of the rail they are strongly ribbed, as shown in the illustration. The supporting plate *J* has a slot cut in it at *K* for adjusting the pivot stud *L* in a longitudinal direction. This stud supports one end of the radius-rod *N*, and the other end is attached to the upper portion of the ram *F* by pivot stud *M*. A regular tool-holder at the lower end of the ram holds the tool *D*. No special arrangement is necessary to allow the saddle to "float" in a transverse direction, as the horizontal feed-screw is used in this case, the vertical feed being simply thrown out of mesh. This permits the ram to float vertically, as controlled by the radius-rod *N*.

Attachment for Concave Turning in a Horizontal Plane

The steel casting shown at *A* in Fig. 18 is turned concave by the same device as that illustrated in Fig. 17, the only difference being

that the radius-rod *N* is pivoted to the ram below the supporting plate instead of above. The operation of the mechanism is exactly the same as that for the convex surface.

Many variations of the devices described in this chapter have been used for generating radial surfaces, but enough have been described to enable the reader to select a method most suited to the particular problem that may require a solution. Adaptations may be readily made to fit almost any condition likely to be encountered in general manufacturing.

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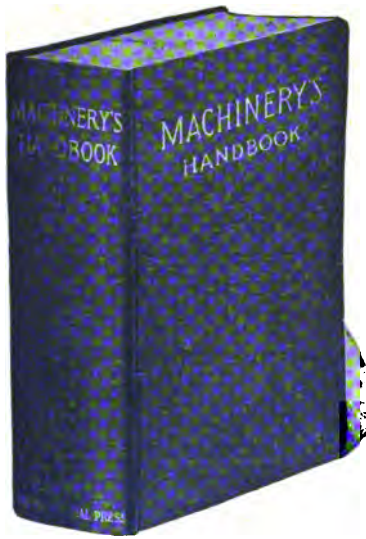

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